

SHIP PRODUCTION COMMITTEE  
FACILITIES AND ENVIRONMENTAL EFFECTS  
SURFACE PREPARATION AND COATINGS  
DESIGN/PRODUCTION INTEGRATION  
HUMAN RESOURCE INNOVATION  
MARINE INDUSTRY STANDARDS  
WELDING  
INDUSTRIAL ENGINEERING  
EDUCATION AND TRAINING

September 1981  
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# **THE NATIONAL SHIPBUILDING RESEARCH PROGRAM**

**Proceedings of the IREAPS  
Technical Symposium**

**September 15-17, 1981  
Baltimore, Maryland**

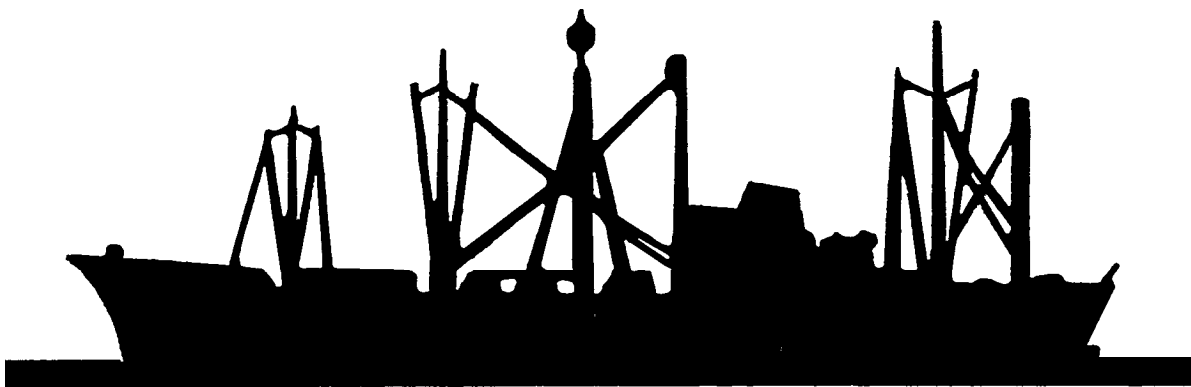
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Proceedings  
IREAPS Technical Symposium  
September 15-17, 1981  
Baltimore, Maryland



INSTITUTE FOR RESEARCH AND ENGINEERING FOR AUTOMATION AND PRODUCTIVITY IN SHIPBUILDING

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## PREFACE

IREAPS is an independent not-for-profit membership corporation founded in April 1981 to direct the 9 year-old REAPS Program. The IREAPS Program is a U. S. shipbuilding industry/Maritime Administration cooperative effort whose goal is the improvement of shipbuilding productivity through the application of computer aids and production technology.

The Eighth Annual IREAPS Technical Symposium, held September 15-17, 1981 in Baltimore, Maryland, represents one element of the IREAPS Program which is designed to provide industry with the opportunity to review new developments in shipyard technology.

The Symposium this year highlighted all aspects of the National Shipbuilding Research Program (NSRP)\* in that presentations were made by all the panel chairmen of the SNAME Ship Production Committee.

The 1981 IREAPS Technical Symposium Proceedings contain most of the papers presented at the meeting. The agenda in Appendix A indicates topics and speakers; Appendix B is a list of symposium attendees. All current SPC-SNAME chairmen are identified in Appendix C.

\* The NSRP is a cooperative effort between the Maritime Administration's Office of Advanced Ship Development and the U. S. Shipbuilding Industry.

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## WELCOME

John C. Estes  
Assistant Vice President  
Shipbuilding Department  
Bethlehem Steel Corporation  
Bethlehem, Pennsylvania

Good morning and welcome to the City of Baltimore and the Eighth Annual IREAPS Technical Symposium. This is a significant pleasure because Baltimore hosted the first REAPS Technical Meeting in 1974. Baltimore has changed a great deal in those 7 years. I am sure that some of you have already seen the downtown and harbor area redevelopment. Harborplace and the new Aquarium are worth a visit. As experienced in the City of Baltimore, change is the most prominent feature of our industry today. We are all experiencing changes in our product specialties, customers, technologies and in many ways, the nature of our business.

In 1974, Sparrows Point Yard was engaged in the construction of VLCC class tankers. Today that yard is building mobile jack-up drilling units for the offshore oil industry, as well as oceangoing barges for integrated tug-barge units. Seven years ago there were active commercial markets for crude oil and special products carriers, for LNG and container ships. Today the emphasis is on an anticipated surge of naval construction, both commercial type support vessels and combat vessels. Until a few years ago steam turbine propulsion was standard for U.S. commercial vessels. Today those vessels are being built and proposed as diesel engine powered and, in some cases, powered by steam from coal fired boilers.

All of these changes create new demands on our production methods and facilities, on our planning and procurement systems and policies.

In response to these challenges, REAPS has changed substantially as well. Ten years ago there was a recognized need for computer aided lofting in American shipyards. As a stimulus to the industry the MarAd made AUTOKON '71 available to U.S. shipyards and established a program of support and

implementation. Thus was born REAPS. Today this program has grown far beyond its initial commitment to computer aided lofting. This spring IREAPS became a corporation committed to the improvement of U.S. Shipbuilding productivity through the development and implementation of a full spectrum of improved systems and manufacturing technology. With the Ship Production Committee and the Shipbuilding Standards ASTM F-25 Panel, IREAPS is an integral part of the National Shipbuilding Research Program. As a corporation, IREAPS is the partner capable of contracting with businesses or agencies for products and services. This should enhance the effectiveness of the other two organizations. While these organizations were originally the product of MarAd initiatives, they now anticipate increased funding by and cooperation with the Navy. IREAPS has therefore become part of a truly National shipbuilding program.

Much interest is being shown recently by our new administration, and by industry, concerning reindustrialization, industrial revitalization, and improved productivity. In these various concepts, capital investment, and the lack thereof, is in the forefront, but equally important is the management aspect. In that regard, recognition is being given to all levels of productivity, including that of management, particularly as it relates to design for production, planning, scheduling and provision and arrangement of facilities.

Management's initiative in applying modern methods and systems will also serve to demonstrate to labor that management recognizes that improved productivity must be obtained by means other than just "speeding up the assembly line".

This symposium reflects this breadth of involvement. You will notice that the entire first day is devoted to reports from Ship Production Committee Panels. The second day includes a number of papers related to the U.S. Navy's contribution to improved productivity. Both the second and third days include presentations addressing the more human aspects of our industry.

All of you who are participating in the program of this symposium are to be commended for your involvement. The interest in the subjects to be discussed is obvious by the attendance and the number and variety of organizations represented in that attendance.

Again, Welcome to the Eighth Annual IREAPS Technical Symposium. I am sure the next several days will be profitable to everyone involved.



## SHIP PRODUCTION COMMITTEE OVERVIEW

Ellsworth L. Peterson  
President, Peterson Builders Inc  
Chairman, Ship Production Committee  
Sturgeon Bay, Wisconsin

I believe "Ship Production Committee (SPC) Overview" needs a little explanation. The SPC, approximately 9 years old, was formed under SNAME Technical & Research Steering Committee and funded by MarAd with some cost sharing by industry. The purpose, to improve productivity in U.S. shipbuilding. This to help U.S. shipyards reduce their costs, make MarAd subsidies less and with the hope of the U.S. being more competitive in the world market. Much headway has been made.

Our projects are published as National Shipbuilding Research Projects. As Chairman of the SPC, we and REAPS thought it would be educational to this symposium to share an overview of our research projects plus the new Panels, SP-4 - Design/Production Integration and SP-9 - Education.

The SPC started with just shipyards. However we soon recognized the need to add others: USCG, USN, ABS, along with our sponsor, MarAd. We recently added design agents and educational people, who train our future marine people, to our membership.

You will be hearing from our program managers on their projects shortly. We have many cost saving projects. They need to be implemented. We are also sponsoring workshops to teach shipbuilding the better way. The program managers will explain.

We are now coordinating with Navy representatives here as well as MarAd. Cooperation between commercial and Navy ships material and equipment needs can make standards work and save dollars for both. Our SPC interfaces with the Navy Manufacturing Technology group and CAD-CAM so we share information and do not duplicate programs. We plan to spend taxpayer's money wisely for they are us.

## SP-2 - OUTFITTING AND PRODUCTION AIDS

Louis D. Chirillo  
Research and Development Program Manager  
Todd Pacific Shipyards Corporation  
Seattle, Washington

### ABSTRACT

SNAME Panel SP-2 initiatives started the now massive transfers of Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI) technology to the U.S. shipbuilding industry. Further, the Panel has continued to participate in systematically extracting more knowledge about the very competitive IHI methods. The projects completed, underway and proposed would, in the absence of guidance be differently assimilated by individuals because of parochial interests. More so than anything else, the National Shipbuilding Research Program publication "Product Work Breakdown Structure-November 1980" provides awareness of how seemingly unassociated Panel SP-2 and other projects are critically related. A senior manager of a large U.S. shipbuilding firm stated: "Without such awareness we will continue to suffer from suboptimal efforts from well-intentioned middle managers trying to incorporate new ideas piecemeal from the bottom up without any recognized overall framework for change."

Traditionalists retard development of shipbuilding methods in the U.S. when they continue to refer to superior Japanese work ethic, facilities, etc. There are surprises in store for them if they address differences in management methods. One surprise is that the product (or zone) oriented methods which characterize shipbuilding in Japan are largely American in origin. Much can be traced to Henry Kaiser, the industrialist who set unprecedented shipbuilding records during World War II. Much was brought to Japan in 1951 by Elmer C. Hann, a former Kaiser shipyard manager.<sup>1</sup> During the next two decades, when it was Japanese national purpose to be foremost in shipbuilding, these methods were continuously developed and repetitively applied and proven in old shipyards, virtually all of which escaped destruction during World War II.<sup>2</sup>

Even the idea to publish Product Work Breakdown Structure (PWBS) is American.<sup>3</sup> The Panel SP-2 research specification fixed the scope, established the relationship with the logic and principles of Group Technology (GT) and provided critical definitions, e.g.:

- A work breakdown structure identifies interim products and their relationships to each other that are necessary for defining and constructing an end product, i.e., a ship or other entity.
- An interim product is a discrete element identified as an objective in a work package. It is a part, subassembly, zone, system, etc. that has been transformed by the application of work.

This emphasis caused the shipbuilding engineers, from Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI) of Japan, who contributed to PWBS to concentrate on their methods for devising ideal interim products. These, when matched to preferred classifications by zone, problem area and stage are much of "... the logical arrangement and sequences of all facets of company operations in order to bring the benefits of mass production to high variety,

mixed quantity production." "This is Group Technology. In a manner of speaking, their expertise is in planning, scheduling and producing interim products; the ship as an entity is incidental. To them, standard-series interim products, i.e., unchanged in problem area and work content regardless of design differences, are more important than standard-series ships.

At this time, the best overall framework of IHI methods is PWBS and it exists only in English. It is the "Rosetta stone" which facilitates shipbuilders' understandings of how insufficient coordination of different functions is the greatest cause of inefficiency in any industrial enterprise. Even IHI people regard PWBS with awe. They are now considering translating it into Japanese, undoubtedly to facilitate training their next generation of shipbuilding engineers and also to facilitate transition to automated shipyards.<sup>5</sup>

The Achilles' heel of the U.S. shipbuilding industry has been identified by Dr. H. Shinto<sup>6</sup> as not enough middle managers who can think analytically about industrial engineering matters. Such people, really shipbuilding engineers preoccupied with interim products, are necessary for coordinating the various material procurement, fabrication and assembly disciplines that characterize shipbuilding. Abilities to integrate hull construction, outfitting and painting, as described in PWBS are now prerequisite for shipbuilders everywhere. There are no other practical options because the current politico-economic climate is characterized by:

- conviction that subsidy insulates from competition, diminishes efficiency, and adversely impacts on long-run performance, and
- inflation and high interest rates focusing attention on minimizing time between contract award and delivery.

Citing pertinent actions by Avondale Shipyards, Inc. in mid-1979 and subsequent progress of integrated processes, a government official expressed the opinion that no other U.S. shipbuilding firm can afford to remain static.

They too must exploit the Japanese shipbuilding technologies, such as PWBS, which Maritime Administration initiatives are making available through the National Shipbuilding Research Program.

Similarly, the U.S. Navy has no other option if it is to avoid further arousing public skepticism of its ability to manage shipbuilding affairs. By any measure, such non-confidence has impaired naval readiness more than even the 7 December 1941 attack on Pearl Harbor. For example, recent criticisms associated with Trident class submarines are not new. Comments such as "... shocking cost overruns . . . and changing specifications while a vessel was being built . . ." have been continuously newsworthy for over a decade.<sup>7</sup> In readiness terms, cost overruns and late deliveries are the equivalents of ships damaged or sunk!

Department of Defense (DOD) Instruction 7000.2 advises shipbuilders to "... be continuously alert to advances in management control systems . . ." It **does not** require "... the use of any single system . . ." Thus, the initiative is open to shipbuilders! Also, the DOD instruction defines a work breakdown structure as: "A product-oriented family tree division of . . . work tasks which . . . define the product to be produced **as well as the work to be accomplished.** . . ." The Navy's Ship Work Breakdown Structure (SWBS) does not fulfill this definition because it is system oriented. Neither does it conform with current U.S. shipbuilding methods nor with the world's most productive methods. Thus, the Navy itself is impeding implementation of advances in management control systems!

Further, the Navy's SWBS is not consistent with the logic and principles of Group Technology. 'PWBS adapted for building naval ships, would conform with the DOD definition and, as proven in Japan, is extremely effective for applying Group Technology to shipbuilding operations.

The Navy, like commercial shipbuilders, must forgo traditional methods for the expanded naval shipbuilding program currently planned. Naval officials are well advised to de-emphasize their overbearing bureaucracies<sup>8,9</sup> and substitute encouragement, if not requirement, for shipbuilders to adopt a product-oriented work breakdown structure as a framework for change. Precedents for applications in naval shipbuilding exist not only in Japan, but also as applied in Avondale for integrated hull construction, outfitting and painting of naval tanker pump-rooms.

A productive shipbuilding industry is an indispensable element of seapower.

## Footnotes

<sup>1</sup>Mr. Elmer C. Hann is currently Vice President, Far Eastern Operations of National Bulk Carriers, Inc. In early 1941 he was the second shipbuilder to join Kaiser at the latter's Richmond No. 1 yard. There he was Hull Superintendent during construction of Thompson Sands vessels for the British. Later during World War II, as General Superintendent in Kaiser's Swan Island shipyard, he had all responsibilities for building the then, very sophisticated T-2 tankers. Mr. Hann was presented with the Order of the Chrysanthemum by the Emperor for outstanding contributions to the Japanese shipbuilding industry.

<sup>2</sup>"Japan's Phenomenal Shipbuilders" by Admiral S. Nakayama, Japan Maritime Self-Defense Force (Retired) and M. Chihaya, U.S. Naval Institute Proceedings, August 1966, pp. 27-39.

<sup>3</sup>"A Study of Shipbuilding Cost Estimating Methodology" for the Maritime Administration by Engineering & Management Sciences Corporation. dated 20 January 1969.

<sup>4</sup>"Group Technology: A Foundation for Better Total Company Operations", by G.M. Ranson, McGraw-Hill, London, 1972, p. 1.

<sup>5</sup>"Shinto's Proposal on Building of Next Generation Ships", Zosen, Tokyo News Service, Ltd., March 1981, p. 17.

<sup>6</sup>Believed by many to be the world's foremost shipbuilding engineer, Dr. H. Shinto graduated from Kyushu Imperial University in 1934. He then entered Harima Shipbuilding & Engineering Co., Ltd. In 1951 he joined National Bulk Carriers, Corp. which had just leased the former naval dockyard in Kure, Japan. In 1960 he became Managing Director of IHI and Manager of the Shipbuilding Division. He was nominated as Executive Vice President of IHI in 1964, then as President in 1972. A consultant for two years after retirement, Dr. Shinto was recently appointed by his Prime Minister as President, Nippon Telephone & Telegraph Corp.

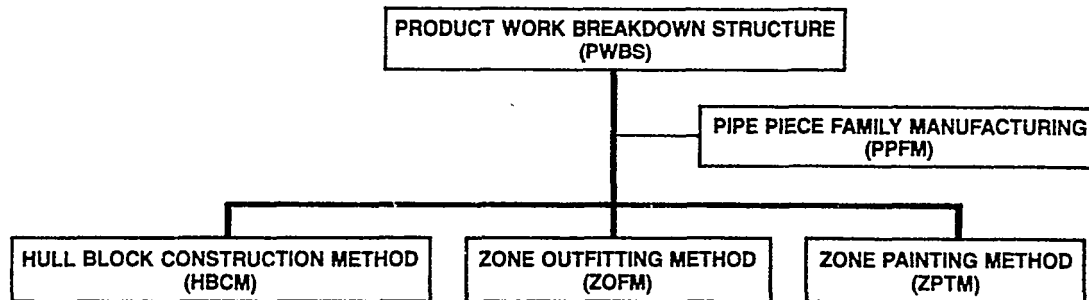
<sup>7</sup>TIME, 21 November 1969.

<sup>8</sup>In the early sixties, seven people were assigned to a Navy resident office during peak construction of guided-missile destroyers (DDG). The shipbuilder did not then have a quality assurance (QA) staff. Since then, the Navy shifted to a surveillance-inspection policy for its own people and simultaneously required the shipbuilder to maintain a QA staff. Recently, for ships (FFG) having similar shipbuilding-problem areas and a production-work rate that peaked at a little more than threefold, the same Navy resident office grew to about sixty people while the shipbuilder had sixty-five assigned to QA.

<sup>9</sup>"Navy Shipbuilding: Building Ships or Bureaucracies?" by Commander Louis D. Chirillo, U.S. Navy (Retired), U.S. Naval Institute Proceedings, August 1975, pp. 38-45.

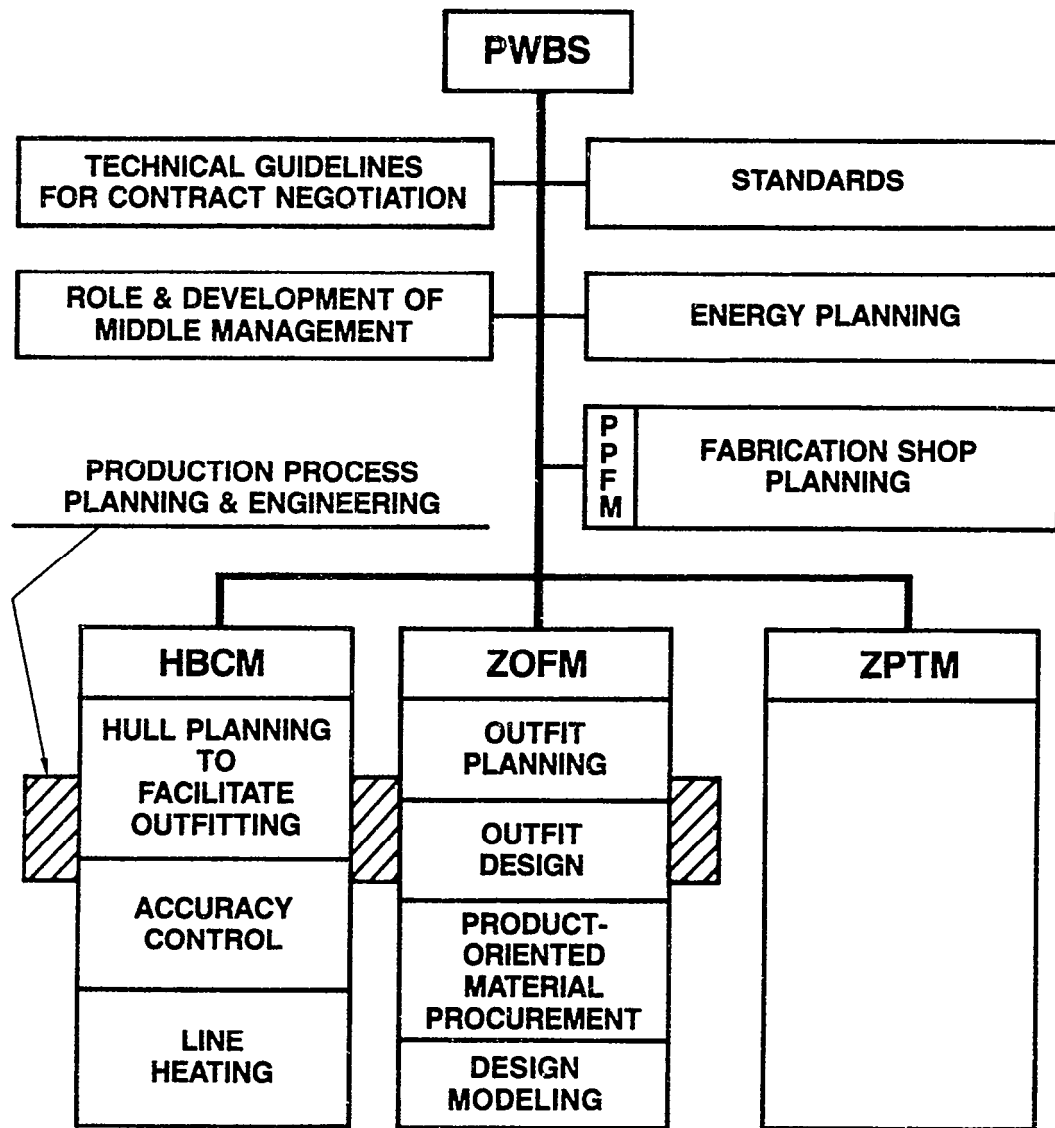
# APPENDIX

## Summary of Panel SP-2 and Related Projects



Product Work Breakdown Structure (PWBS) applies to any industrial process. As developed for shipbuilding, it features three basic methods. Each addresses a distinct type of work. As all are zone/problem-area/stage oriented, they can be readily integrated. Also, they facilitate real and virtual flow processes in accordance with the principles of Group Technology. A fourth supporting method which is problem-area/stage oriented, facilitates the application of Group Technology for fabricating parts such as pipe pieces.





A number of subjects being addressed by the National Shipbuilding Research Program derive from Product Work Breakdown Structure (PWBS). None require investment in facilities!

## Hull Block Construction Method (HBCM)

- **Hull Planning to Facilitate Outfitting-US.** shipbuilders are confronted with the need to wean traditionalists from the premise that "... ready for outfitting dates must first be met in the hull production area." This is because the most competitive shipbuilders have proven that it is possible to devise blocks that facilitate outfitting and painting while at the same time applying Group Technology to hull parts, sub-blocks and blocks in order to achieve the benefits of both real and virtual flow lanes. A book is being prepared which should reorient hull-construction planners and teach outfit and painting planners hull-construction options.
- **Accuracy Control-**A common problem encountered in shipbuilding is difficulty in joining hull blocks during erection due to inaccuracies such as in overall dimensions and misalignment of structural members. Considerable time and labor is needed to correct such errors. Moreover, their correction at the erection site is not conducive to safety. The science of Accuracy Control is applied by foremost shipbuilders to curtail errors in each work process, i.e., preparing templates, marking, cutting, fitting, welding, etc. The accumulated error at the erection stage is limited within a tolerance which assures structural integrity. Also, Accuracy Control is a means of controlling the amount of work performed at each stage so that none is arbitrarily passed downstream where it would disrupt real or virtual flow lanes. For this reason and because there is considerably less rework, productivity is enhanced. A book is being prepared which addresses: importance, approach, errors in each process, merger of errors, applications in production, related jobs and practical suggestions.
- **Line Heating (Flame Bending)-**The ability to form extraordinary shapes by heating and cooling has been developed and applied as a science by leading shipbuilders. It is employed as an adjunct to Accuracy Control. It features: less need to invest in facilities, improved accuracy and enhanced productivity when combined with the use of presses and rollers. Further, line heating is applied at all manufacturing levels, e.g., for parts, sub-blocks and blocks in order to correct distortion. An illustrative publication is being prepared which will describe effects on accuracy, principles and applications.

## Zone Outfitting Method (ZOFM)

- **Outfit Planning-**Published in December 1979, it fulfilled its objective to "... record optimum outfit planning techniques in order to facilitate the training of new outfit planners and a better understanding of outfit requirements by other shipyard functionaries." It introduced zone outfitting, as distinguished from less efficient preoutfitting, pertinent terminology and design methods, and described the reliance on material control which impacts on the organizations in the world's most effective shipyards.
- **Outfit Design-**Methods used by the foremost shipbuilders are known to be based upon the principles of Group Technology and to have produced tremendous benefits even without new facilities. They require more designer understanding of fabrication and assembly methods so that virtually all planning can be included in work instruction drawings and their structured material lists. The objective of this project is to describe the II-II methods, which in some instances have reduced design manhours required to ¼ of those required by traditionalists. It will also describe techniques used for accelerating material requirements definition (70% defined at 30% design completion) and minimizing the overall design time required. Concepts such as the use of standards, design modules, etc. that were introduced in "Outfit Planning-December 1979" will be more thoroughly describe.

- **Product-oriented Material Procurement**-For the procurement of outfit materials, leading shipbuilders have developed suppliers and subcontractors that efficiently function as extensions of their shipyards. Because of certain arrangements there is mutual understanding of each other's needs so that many small supplier and subcontractor organizations effectively assist shipyards to maintain standards and inventories and by performing painting and palletizing, i.e., the delivery of material by zone requirements. As U.S. shipbuilders have started the shift to zone-oriented methods, there is need to advise them of effective zone-oriented material procurement techniques.
- **Design Modeling**-Shipbuilders throughout the world have developed design modeling as a simplified means for creating the detail design of a complicated machinery space such as a ship's engine-room. They were motivated by the decline in experience levels of the people available. Moreover, recent research has disclosed a practical photogrammetric method for obtaining 3-dimensional coordinates from a model for direct entry into a computer. Thus, three "tools" are now available to detail designers, each of which is uniquely productive when certain conditions exist. More has to be described about design modeling so that shipbuilders may better select one or a combination of the design-method alternatives.

### **Zone Painting Method (ZPTM)**

- Panel 0-23-1 has cognizance. -Attention should be focused on changes in current painting specifications in order to permit zone-by-stage control, i.e., integration of painting with hull construction (HBCM) and outfitting (ZOFM). The benefits are safer working conditions, minimization of staging, more even distribution of painting manhours over an entire shipbuilding project and better productivity.

### **Related to HBCM, ZOFM and ZPTM**

- **Production Process Planning & Engineering**-Other research, particularly that which produced "Product Work Breakdown Structure-November 1980", proved that the most productive shipbuilding methods are primarily based upon the use of Group Technology. The very effective IHI production process planning and engineering is commonly associated only with the world's first rationalized shipyard, IHI Yokohama opened in 1964, and newer shipyards. However, they are also applied in two older IHI yards, Kure (1903) and Aioi (1913), to the extent that both are among the world leaders particularly for a mix of outfit-intensive ships. Thus, the objective of this research is to describe pertinent methods, particularly the interaction between field engineers and designers, which maintain coordinated and uniformly loaded, virtual and real process flows.
- **Contract Negotiation of Technical Matters**-There are various technical matters in addition to contract design that are of mutual concern to a shipbuilder and ship buyer. These at least include:
  - building methods (HBCM, ZOFM, ZPTM & PPFM), shipyard practices (standards) and major items of a painting schedule,
  - design methods (standards),
  - list of major materials to be furnished by suppliers,
  - list of drawings for buyer's approvals,
  - inspection standards and procedures, and
  - progress reporting methods.

One U.S. shipyard has already completed a successful negotiation with a buyer as described in the foregoing and reported that real progress upon contract award ... was about four months ahead of where they would have been otherwise." U.S. shipbuilders need more information about such negotiations which some of their customers already encountered when they had ships built abroad.

- **Role & Development of Middle Management**-Dr. H. Shinto, widely recognized as the world's foremost shipbuilding engineer, has identified the lack of college educated, or equivalent, middle management as the singular reason why U.S. shipbuilders' productivity is significantly less than that of their counterparts in Japan. In the organization for shipyards as developed for Ishikawajima-Harima Heavy Industries Co., Ltd. by Dr. Shinto, people having achieved college level proficiencies in various disciplines (i.e., not only in naval architecture & marine engineering) are assigned systematically in accordance with certain career patterns. The objective is to fully develop them as shipbuilding engineers, i.e., industrial engineers who specialize in the development and execution of material procurement, fabrication and assembly matters that characterize shipbuilding. Such people are rotated in various positions of responsibility including the management of fabrication shops and assembly sections. Thus, they appreciate the interdependence of different kinds of work and have as a consequence, developed extremely competitive, integrated hull construction, outfitting and painting. The end product will be a book which will recommend career patterns for managerial people in U.S. shipyards. It will at least include educational and/or experience prerequisites, career alternatives (e.g., in design vs. in production) and prerequisite job experiences for specific assignments at specific managerial levels.
- **Standards**-Panel SP-6 has cognizance. This effort is important to SP-2 activities because Panel SP-6 has redirected its' research to take advantage of IHI's extraordinary methods for classifying and maintaining standards. Much of the implementation of Panel SP-2 end products will be facilitated when shipbuilders exploit standards beyond those which apply to just material items, i.e., for reusable machinery arrangements, design modules, patterns and panels as described in "Outfit Planning-December 1979".
- **Energy Planning**-The objective of this project is to facilitate shipbuilders' determinations of cost effective energy conservation techniques for fabrication and assembly processes. A specific goal is a set of energy indices analogous to those used for monitoring manhours as shown in "Product Work Breakdown Structure-November 1980" (Figure 54) broken down by classes of interim products. These could be energy-units/month consumed per fabricated parts weight, per subassembly weight, per subassembly welding parameter, etc. As monitoring all may not be practical, the objective includes some qualified way to apportion energy metered at a single location to various manufacturing levels or work stages. This research could make it practical to consider the energy required per work package as another means for determining its productivity value.

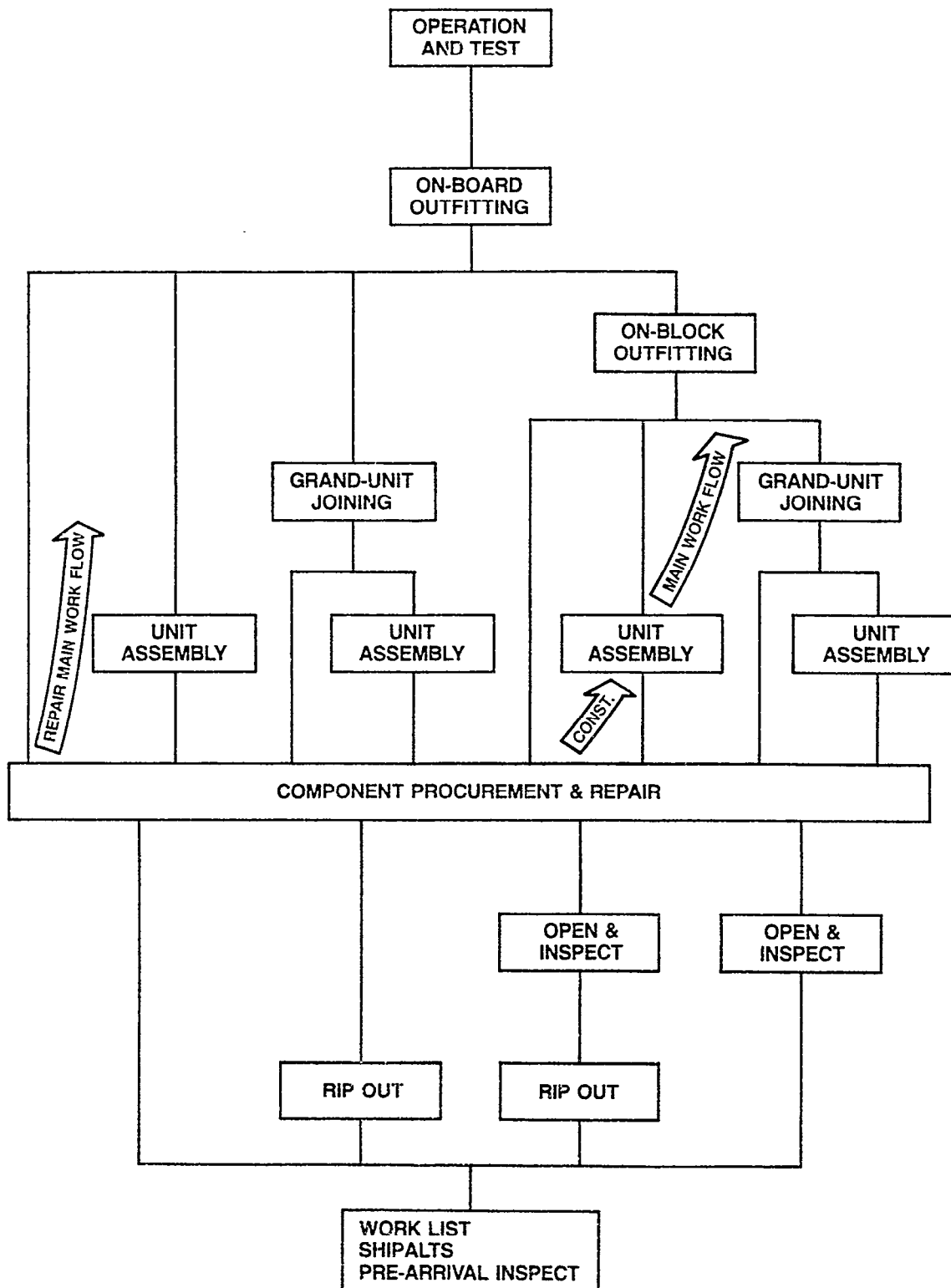
### **Pipe Piece Family Manufacturing (PPFM)**

- **Fabrication-Shop Planning**-This work, although being performed in the context of pipe-piece manufacturing, should be useful for any other shop's work provided it features high variety, mixed quantity production. The project's goal is to elaborate on information contained in "Outfit Planning-December 1979" (Figures 2-13, 2-14, 2-17 and 2-18). Addressing shop managers, their field

engineers and designers, it will show how piece identities and their classifications for family manufacturing assigned by designers are linked to assembly work packages through material lists. It will suggest problem area, i.e., family, classifications that designers should consider. Thus, it will encourage structured material lists as the means for ordering material and performing fabrication by lots per family even for different systems in different ships being constructed simultaneously. In other words the project addresses Group Technology applied to a fabrication shop.

### **Suggested Future Projects**

- **Product Work Breakdown Structure (PWBS) for Ship Repair-**The unqualified success of zone-by-problem-area-by-stage control for outfitting suggest applicability to ship repair. During an October 1980 interview, Dr. H. Shinto confirmed applicability provided the overhauls are large enough to "...justify engineering involvement." Certainly in the U.S., overhauls of most naval ships are large enough; some even exceed the costs for building commercial ships. Dr. Shinto specifically confirmed that PWBS has been applied to conversions such as when shifting from steam to diesel propulsion. Precedent exists in the form of application dictated by circumstances like in the congested sail-area of a modern submarine. Another, by a private ship-repair yard already featured zone-by-stage control of all trades in a congested pump room of a naval tanker. Precedent exists in a naval shipyard where recently a sponson was outfitted on-block before it was attached to an aircraft carrier.
- **Indices for Monitoring Man-hours, Progress and Productivity-**As shown in "Product Work Breakdown Structure-November 1980" (Figures 5-3 and 5-4) the effectiveness of PWBS is due primarily to the separation of fabrication shops and assembly organizations to match specific classes of interim products. The performance indicators employed are custom devised for each. Although those shown are more than what are customarily applied in the U.S., even more indices are used by IHI. For example, only two productivity indices are shown for Pipe Piece Family Manufacturing, i.e., manhours/manufactured weight and manhours/manufactured piece. These are known to be supplemented with pipe piece welding parameter/manhour and to be broken down by pipe-piece families. More such information would assist U.S. shipbuilders in identifying the costs that are normal for their work forces and facilities.



## SP-1/SP-3 - SHIPYARD FACILITIES AND ENVIRONMENTAL EFFECTS

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### FACILITIES

The Ship Production Committee of the Society of Naval Architects and Marine Engineers re-activated Panel SP-1 Facilities July 20, 1978.

Avondale Shipyards Inc accepted the chairmanship and agreed to be the primary sponsor. Presently we have 21 active members from 17 shipyards plus MarAd representation.

During the July 1978 meeting of Panel SP-1 (Facilities) it was suggested that the panel develop a consensus specification for long-range facility plans. The purpose of the consensus specification is to provide a standard format and criteria for the development of facility plans. This would be a tool for use by MarAd and a specific shipyard in conjunction with the proposed facility modernization planning program.

A 5-day working conference was held in Atlanta Georgia. Twenty-two representatives from 12 major shipyards attended the 5-day conference and currently have a common approach for the development of long-range plans.

The second step of this effort was to prepare proposals, on a voluntary basis, for one or more shipyards to develop a long-range plan for their respective yard. The detailed proposals were submitted directly to MarAd.

Panel SP-1 (Facilities) currently has a three-phase objective emphasizing improved productivity.

Phase I - Enhance the Shipbuilding Industries Long-Range  
Facilities planning Efforts

Phase II - Determine a Feasible Method of Instituting a Cooperative High Risk Facilities Program

Phase III - Determine a Feasible Method of Instituting a Cooperative Facilities Modernization Program

Our efforts are directed toward achieving this three-phase objective, placing emphasis on cost effective producibility. Five shipyards are participating in the long-range facility planning effort.

#### LONG-RANGE FACILITIES PLAN STATUS

<u>Shipyard</u>	<u>Mo/Yr Completion</u>	<u>Remarks</u>
NASSCO	March 1982	
Todd, Louisiana	Completed	Final Report in work
Peterson Builders Inc	Requesting a time extension	
Newport News	MarAd Contracting in work	
Avondale Shipyards Inc	June 1982	

#### SUMMARY AVONDALE SHIPYARDS LONG RANGE FACILITY PLAN

The primary objective is to decrease the total time required from contract award to delivery of vessels, along with increasing our productivity so as to reduce cost.

##### A. Phase I: Long-Range Facility Plan

We have completed the technology evaluation. The Long-Range Facilities Plan is rescheduled for completion including integration of the technology survey during the month of June 1982.

##### B. Phase II: Implementation

The following itemized objectives provide the management mechanisms assuring proper implementation and application of the prioritized findings resulting from the technology evaluation. This implementation program is expected to be completely operational and put into effect on Avondale Shipyards, Exxon Contract.

1. Implement the IHI System of Accuracy Control at Avondale Shipyards Inc
2. Implement the IHI System of Production Planning at Avondale Shipyards Inc



3. Implement the IHI System of Computer Application at Avondale Shipyards Inc
4. Implement the IHI System of Design Engineering with Procurement Specifications at Avondale Shipyards Inc

C. Second Round Effort: Implement Process Lanes

As a second round effort, Avondale has submitted an abstract proposing the implementation of Process Lanes to MarAd for funding.

## BACKGROUND AND PROGRESS

A. Phase I: Long-Range Facility Plan

Avondale's original proposal, which was submitted to MarAd on May 23, 1979 we rescoped and resubmitted on June 27, 1979. The reason for resubmittal was based on the rough appraisal of Avondale Shipyards operations after studying the MEL Technology Survey, the Livingston/IHI Technology Transfer, Todd Shipyards outfit planning document and the Shipbuilding Industry's Consensus Specification for a long-range facility plan. Our study has indicated that to develop a long-range facility plan, we have to take advantage of all the technological data, which has been developed under the MarAd research program, because this would have direct - affect upon the long-range plan.

In June 1979, ASI requested and received a quotation for a survey of Avondale Shipyards Inc from IHI Marine Technology Inc. In July 1979, we entered into a contract with IHI to do the survey. April 22, 1980, we received a letter of Contract MA-80-SAC-01031, for a long-range facilities plan. September 26, 1980 we signed the contract with MarAd. We completed the technology evaluation and received a preliminary report from IHI October 1, 1979. Decisions presently being analyzed regarding pre-outfitting are influencing material flow and material handling. These factors impact the completion of our long-range facility plan. Based on these circumstances, we requested that the period of performance (Article II) of the contract be extended from June 16, 1981, to June 16, 1982.

B. Phase II: Implementation

After completion of the technology evaluation, the recommended improvements prioritized the implementation of the accuracy control, production planning, computer application systems, and design engineering for zone outfitting with procurement specifications for material to supply zone outfitting. December 28, 1979, we submitted our proposal to MarAd for implementation of the four items.

ASI has made schedule adjustments predicated on implementation and application of these four key management mechanisms. The Exxon contract will be used as a basis for measurement of improvement in our productivity and cost effectiveness. We anticipate an approximate 3 month flow time reduction from laying the keel to delivery date.

We awarded a subcontract to our consultant "IHI Marine Technology for the implementation effort before the formal contract was issued by MarAd. Avondale sent a team to Japan on August 4, 1979, to do an in-depth study of the IHI engineering and manufacturing methods. The on-site survey was started August 27, 1979, at our facility. We understand from Mr. Garvey that this project will be the first funded by cooperative agreement through the National Shipbuilding Research Program. We expect a definitive signed contract with MarAd in the near future.

C. Second Round Effort: Implement Process Lanes

Early in the technical evaluation, we determined the magnitude of the IHI recommendations. IHI had dedicated substantial time and effort since the end of World War II developing and refining their technology. We have concluded that Avondale, or any other shipyard, would derive significant improvements in productivity by the integration of this technology into their existing operations. Inasmuch as these approaches impact all functional operations in shipbuilding firm (customer, Coast Guard, Maritime Administration, vendors, etc), there remains considerable uncertainty as to the difficulty, costs and benefits of the applications proposed.

For this reason Avondale did not propose to implement all the IHI recommended changes at one time. Our criteria for a selection of a first-round implementation program considers many factors which in summary attempts to realize the most significant improvements in productivity with the least amount of disruption. After careful consideration Avondale proposes the implementation of Process Lanes as a second round effort.

### PIPE SHOP

Approximately 5 years ago Avondale started a feasibility study of a semi-automatic pipe handling system and fabrication facility due to the high cost of ship piping systems. This project, it turns out, will be a major management improvement as well as a cost improvement package. In developing this study we determined that a major change must be made in our method of designing piping as well as in our shop management program.

During the development of the shop management program, which is required to fully implement the pipe shop project, our Data Processing Department investigated various programs that could be utilized without major development cost. The COPICS provided scheduling systems which can include: business planning, production planning, etc.

The study revealed that through automation a percentage of the required man-hours can be reduced in the following functions: handling, 68%; fitting, 55%; welding, 35%; cleaning, 79%; and coating, 86%. These percentages are based on LASH vessel construction since all basic data are applicable to this series of ships. An overall percentage reduction in fabrication man-hours equates to approximately 39.8% per ship (note 30,000 man-hours/146,000 dwt tanker). We held a facility demonstration of the pipe shop and software during the April 1981 Ship Production Committee meeting at Avondale Shipyards.

#### MAJOR PRODUCTIVITY STUDIES IN PROGRESS CURRENTLY

MarAd has authorized Avondale to conduct a study concerning the economics of the installation of beam lines in shipyards. The beam line, for your information, would be capable of deflanging structurals, cutting all shapes, angles, beams and channels. The facility would be capable of processing 35,000 stock pieces per year on a two-shift basis for structurals and it would include marking with an accuracy of 1/25 of an inch. Preliminary return on investment of this facility is extremely high; it appears that a 60% reduction in man-hours can be obtained with this system. Test cases that have been run on small units indicate that these results can be obtained.

Another MarAd project we are studying is a semi-automatic method to assist in the prefabrication, fabrication and assembly of webs, beams, floors, etc. The system provides a method which will reduce the labor, material handling, welding and space required for storage as well as manufacturing. The work within each functional area will be performed by use of adjustable jiggling, welding gantries and other mechanical methods. Substantial emphasis will be directed toward automatic welding. Preliminary tests indicate a 43% reduction in man-hours with this system.

## ENVIRONMENTAL

During 1979 we recommended that Panel SP-1 (Facilities) and SP-3 (Shipyard Environmental Effects) be combined into one panel. The logic being that the functional responsibility generally falls under the facilities department. We thought the combined panel would consolidate our industry's efforts regarding industry consensus input during the comment period of proposed federal regulations.

We coordinate our efforts with Shipbuilders Council of America Environmental Committee when dealing with governmental agencies such as the Environmental Protection Agency, the Department of Labor (OSHA), the U.S. Coast Guard, and the Department of the Navy. The shipyards, on an individual basis, have to address their respective state and local regulatory agencies to meet the intent of their regulations.

During the proposal period, part of our commitment is to ensure that the regulations are feasible regarding compliance as well as cost effectiveness. We have submitted comments to regulatory bodies as well as conducted independent studies to establish guidelines for use in the development of cost effective regulations.

We have focused on such issues as: (1) draft development document for the shipbuilding and repair industry drydock points source category; (2) methods of receiving sewage from vessels using drydock facilities; (3) programs for complying with National Pollutant Discharge Elimination Standard Permit requirements; (4) penalties for violation of Federal Water Pollution Control Act (FWPCA); (5) certificates for financial responsibility; and (6) the OSHA blasting standard development document.

During the recent past the shipbuilding and repair industry through Panel SP-1 (SNAME) and the Environmental Committee of SCA have focused our attention on hydrocarbon emissions. Several approaches have been considered; changing the solvent, inhibiting the photochemical reactivity (Rule 66 Calif), developing high solid coatings, developing water base coatings, utilizing carbon absorption and/or incineration. Carbon absorption or incineration can provide 90% emission control, however, the cost impact is prohibitive. In most cases, this type of emission control could cost as much as the paint

building. During the past 3 to 5 years most military specifications and commercial paints comply with Rule 66. It must be noted that the shipbuilding and repair industry uses the paint specified by the owners in most cases.

Panel 023-1 of SNAME Ship Production Committee has accomplished substantial gains in the use of high-solid low-solvent coating. This industry effort is over and above Rule 66 compliance. Research and development of effective water base coatings for ships is being conducted. Under the Reagan Administration the volume of proposed regulation has definitely declined. Most shipyards are occupied with compliance to existing regulations in such areas as the consolidated NPDES Permits, RCRA; Hazardous Waste, Hazardous Material, Individual approaches regarding filing as a transporter, generator, treater, disposer and storage of Hazardous Waste. SP-1 will continue to keep abreast of regulatory change which may adversely influence the shipbuilding and repair industry.

## A PROGRESS REPORT ON THE IREAPS PROGRAM

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IREAPS Program Manager  
IIT Research Institute  
Chicago, Illinois

The Institute for Research and Engineering for Automation and Productivity in Shipbuilding (IREAPS) is an organization which conducts an industry/government cooperative program for enhancing U.S. shipbuilding capabilities through development and implementation of improved systems and manufacturing technology.

### PROGRAM ACTIVITIES

The primary thrust of the IREAPS program is the conduct of research and development projects for a variety of design and production processes in the shipyard. Such projects are initiated and pursued only upon consensus of the participating organizations and are not considered complete or successful until they have been implemented under actual shipyard production conditions. Services for participants provided by IREAPS through a technical manager include:

- Technology Assessment--periodic appraisals of the latest technologies in a variety of industries for application to current problems in U.S. shipbuilding processes.
- Technical Support--technical assistance to participating organizations in implementation use, modification, and maintenance of IREAPS developments.
- Technical Information Services--through the IREAPS Shipbuilding Technology Library an extensive collection of related literature and computer software is made available to the participating organizations.

Additional IREAPS services provided to the entire shipbuilding community include:

- IREAPS Technology Bulletin--a periodic synopsis of articles appearing in worldwide publications of interest to the shipbuilding community. IREAPS participants may order copies of cited articles free of charge; others at cost.

- IREAPS Technical Symposium--an annual symposium providing the industry with a single forum for gathering information through formal technical presentations on the state of the art. All are invited. The registration fee is waived for IREAPS participants.

#### IREAPS PROJECTS

IREAPS-sponsored projects are initiated and pursued under the following scenario.

- The participating organizations:
  - Identify common problem areas
  - Recommend specific R&D projects to address these areas
  - Monitor ongoing projects
- The U.S. Maritime Administration (MarAd) and other Government agencies:
  - Provide financial support to IREAPS participants on a cost-sharing basis; or other contractors, for the development projects.
- The IIT Research Institute (IITRI):
  - Serves as technical manager.
  - Provides technical and administrative services for the IREAPS participants to assure smooth functioning of the program.
  - Conducts selected developments specified by the IREAPS participants.

Current project status is summarized in the accompanying table.

#### ORGANIZATION

IREAPS is an independent not-for-profit membership corporation founded in April 1981 to direct the g-year-old REAPS program. The Institute was formed for the purpose of providing a vehicle through which the REAPS program participants could assume an increasingly active role in establishing and broadening the program agenda and directing its operation, as well as raising the level of the program visibility within each organization. Personnel from each IREAPS organization participate in:

- The Board of Directors--meets at least once a year to develop program policy and direction.

# IREAPS PROJECT STATUS

PROJECT	DESCRIPTION	DEVELOPER	SCHEDULED COMPLETION	IMPLEMENTATION FOLLOW-ON
HULL DEFINITION FAIRING	Adapt to commercial use and document a Navy developed program for hull surface definition. Perform program evaluation.	NNS&DD& CONTRACTOR	COMPLETE	Workshop August 1978. Used in production at BIW, NNS, McDermott, Peterson, General Dynamics and Sun Ship.
N/C FRAME BENDING MACHINE	Develop and demonstrate a fully automated CNC frame bending machine.	MarAd/NSF CONTRACTOR	COMPLETE	Full capability and installation at NASSCO.
DAMAGED STABILITY PROGRAM	Develop and document computer programs to perform damaged stability analysis of ship and non-ship forms.	BETHLEHEM	COMPLETE	Workshop Dec. 1977. Used in production at Beth Ship.
COLD TWIST FORMING OF STRUCTURAL SHAPES	Demonstrate the feasibility of twisting structural shapes cold using inexpensive dies in a hydraulic press.	IITRI	COMPLETE	Full capability being fabricated at NNS for production use.
GRAPHICS AND COMMUNICATIONS TERMINAL	Develop software to allow minicomputer-based system to concurrently verify N/C "tapes" and perform remote computer communications.	IITRI	COMPLETE	Installed for production use at Beth. Steel & BIW.
PIPE DETAILING (RAPID) SYSTEM	Minicomputer-based system for digitizing piping systems to produce fabrication instruction, bill of materials and shop sketch.	NNS&DD	COMPLETE	Workshop Fall 1979. To be applied in production at NNS.
'ARTS DEFINITION SYSTEM	Develop an interactive graphics system to support the definition of structural parts at a CRT. Interactive nesting and the generation of shop drawings.	NNS&DD	FEB. 1982	
COMPUTER ASSISTED COST ESTIMATING	Develop an estimating methodology which makes use of computer assistance and demonstrate its feasibility.	NASSCO	JAN. 1982	
PRODUCT INFORMATION SYSTEM - ASK 1 STRUCTURAL INFORMATION REQUIREMENTS SPECIFICATIONS	Develop a list of information requirements dictated by engineering design planning and production functions for structure use in the design of a structural database.	IITRI NNS&DD BATH PETERSON NASSCO	APR. 1982	
INTEGRATED HULL FORM DESIGN	The objectives of Phase I are to collect, implement, distribute and maintain existing computer aids which meet IREAPS yards requirements for early hull form design.	IITRI	DEC. 1981	



- The Technical Committee--meets at least four times a year to make project recommendations and to direct the conduct of the program
- Advisory Groups--provide technical guidance to developers on specific projects - established for each major development activity.

## FUNDING

The cost of operation of the Institute, the services of technical manager, the IREAPS program and the development projects carried out within the program are shared between the Maritime Administration, other sponsoring government agencies and its industry members.

## MEMBERSHIP

IREAPS offers three membership categories:

- Regular Membership--open only to U.S. shipyards
- Associate Membership--open to first-year shipyard members and U.S. organizations "related" to the shipbuilding industry
- Affiliate Membership--open only to educational institutions

A regular member of IREAPS has voting representation on both the Board of Directors and the Technical Committee. The Board of Directors determines the overall policies of IREAPS and the Technical Committee provides direction in the selection of projects aimed at improving shipyard productivity. A regular member can also chair an advisory group whose major function is the management of a specific development project.

Associate and affiliate members are nonvoting participants of IREAPS and as such are not eligible for representation on the Board of Directors or Technical Committee. These memberships were created to accommodate and encourage participation in IREAPS by organizations related to the shipbuilding industry. An associate/affiliate member is entitled to attend various committee and advisory group meetings. Such interaction with shipyard personnel offers IREAPS members the opportunity to form valuable contacts and offers a medium for the exchange of ideas aimed at improving shipyard productivity.

## DUES

The yearly fee for shipyard regular member participation in IREAPS is \$10,000. First-year shipyard organizations may elect to become associate members for a \$5000 fee. Design agents may join IREAPS as associate members for a yearly fee of \$5000. Educational institutions may join IREAPS as affiliate members for a \$500 fee.

## CURRENT PARTICIPANTS

The following organizations are currently members of IREAPS:

Avondale Shipyards Inc  
Bath Iron Works  
Bethlehem Steel Corporation  
General Dynamics  
J. J. Henry Company Inc  
McDermott Incorporated  
National Steel & Shipbuilding Company  
Newport News Shipbuilding  
Peterson Builders Inc  
Todd Pacific Shipyards  
University of Michigan

## PROCEDURES FOR BECOMING AN IREAPS PARTICIPANT

Joining IREAPS is accomplished by petitioning the Board of Directors for membership in the form of a letter accompanied by the appropriate membership fees. The amount is determined by prorating the appropriate membership type fee on the basis of time remaining in the current fiscal year which runs from October 1 through September 30. For more information contact E. R. Bangs, IREAPS Program Manager, 10 West 35 Street, Chicago, IL 60616; phone 312/567-4608.

## SP- 4- DESIGN/PRODUCTION INTEGRATION

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### ABSTRACT

The Design/Production Integration panel was established by the Ship Production Committee of SNAME on April 23, 1981. The panel is the result of the recognition by the shipbuilding industry that design is the first stage of the production cycle. The overall time from award to delivery, cost and quality of the product is largely determined during the initial planning and design stages.

The Design/Production Integration panel provides a needed vehicle for important design and planning involvement in the productivity improvement work of the SNAME/Ship Production Committee. The work of the panel is currently categorized in terms of two programs: Design for Producibility, and CAD/CAM.

## PREFACE

The title of the proposed panel has evolved along with the original concept and scope of work.

The initial nomenclatures of "Organization for Production" and "Production/Engineering Integration" are no longer viable.

The word "organization" has become synonymous with personnel charts to many in the shipbuilding industry. The inordinate preoccupation of the industry with organization structure, rather than integrated functions, is perhaps inevitable considering the frequent reorganizations at the shipyards. The tasks to be undertaken by the panel are functional needs and are independent of shipyard organization. The term "organization" has been discarded.

"Production/Engineering Integration" has been replaced by "Design/Production Integration." Design comes first as the initial step in the production sequence. The "engineering" has been omitted in recognition that engineers are also in production.

Planning for Design/Production Integration would adequately stress the importance of the planning function. Because the need for planning and action is implicit, and again for the sake of brevity, the title has become

### Design/Production Integration

Paraphrasing Mr. Wiedenhaefer of Grumman Aerospace during his presentation on CAD/CAM at the Atlanta meeting, the objective is to remove the bar between design and production. Hence, our logo

Design Production  
Integration

## I. PANEL BACKGROUND AND OBJECTIVES

The National Shipbuilding Research Program was established by the Maritime Administration and the Ship Production Committee (SPC) of The Society of Naval Architects and Marine Engineers (SNAME) following enactment of the Merchant Marine Act, 1970. Provisions of this legislation charged the Secretary of Commerce with the responsibility to "collaborate with...shipbuilders in developing plans for the economical construction of vessels" (Section 212(c)). The shipbuilding industry direction for the program is provided by the Ship Production Committee which is responsible for the cooperative industry program to develop improved technical information and procedures for use by U. S. shipyards in reducing the cost and time of designing and building ships while improving quality.

The need for U. S. shipbuilders to develop an integrated design and production system resulting in lower costs and reduced time between contract award and delivery has been generally recognized. The communication of data on foreign shipbuilding practices through the efforts of the SNAME Ship Production Committee and the Maritime Administration's National Shipbuilding Research Program brought this need into sharp focus. Improvement of the interfaces and communication between design and production is only a partial solution. The need is for full integration of the two functions with design being considered as the first step in the production sequence.

Newport News Shipbuilding (NNS) perceived the need for this important conceptual change in the basic approach to shipbuilding. Research and discussion with our counterparts in all sectors of the U. S. shipbuilding industry confirmed the commonality of the need for design/production integration.

NNS presented a brief paper to the executive committee of the SPC at their meeting in Philadelphia, October 13-17, 1980, to determine if that body considered the subject worthy of a follow-on effort. Consensus approval and a specific directive was given for a conference/workshop to assess the shipbuilding industry's demand for an SPC panel on this subject and to develop a task outline should the demand exist.

The SNAME/SPC conference and workshops were held in Atlanta from January 18 through 21, 1981. Attendance included participants representing 10 shipyards, two universities, MarAd, ABS, National Academy of Science, IIT Research Institute, design agent and consulting firms. The extent of the recognition of the problem and the demand for an industry-wide approach to the solution exceeded our expectations, as did the professionalism and dedication of the participants. Consensus approval of the participants for the necessary industry-wide approach to the subject of design/production integration was certainly provided. The tasks for the proposed panel were outlined and the scope of work considerably broadened. The meeting was a gratifying and learning experience for all who participated. Fig. 1 depicts the primary area of panel activity.

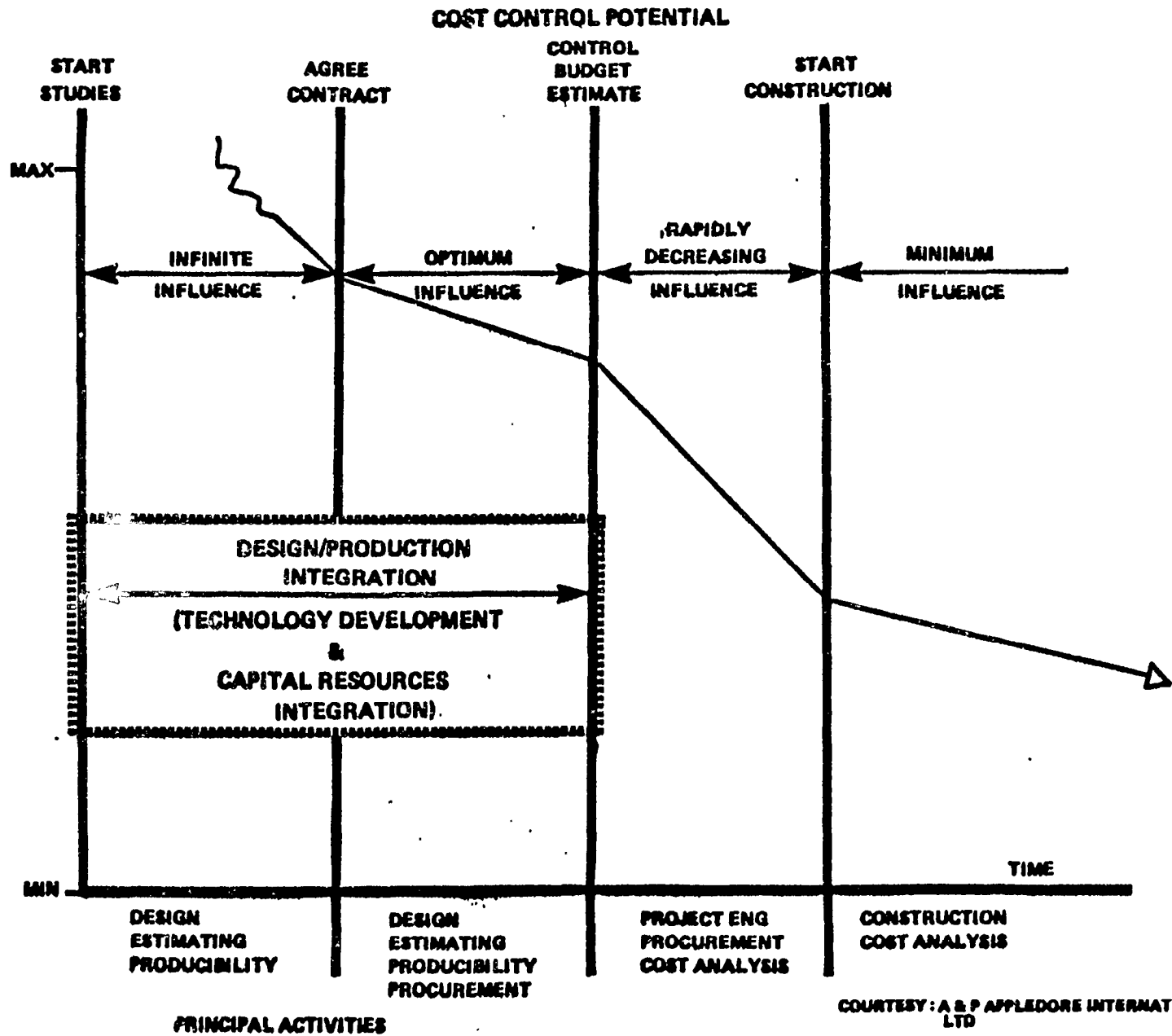


Fig. 1

The Conference/Workshop proceedings were transmitted to the Ship Production Committee on February 25, 1981.

The Ship Production Committee meeting in New Orleans on April 23-24, 1981 approved the establishment of the Design Production Integration Panel SP-4 with a FY 1982 budget of \$400 thousand. (Fig. 2)

## II. FISCAL YEAR 1981 ACTIVITIES TO-DATE

The Design Production Integration panel provides a much needed forum for important design involvement in the work of the SNAME/Ship Production Committee. This involvement is inherent in the concept of design being the initial stage of production. The interactive communication between planning, design, and production provides the basis for productive and usable panel output.

The panel is designed for the interaction of owners, governmental departments and agencies, design agents, consultants, universities and, of course, shipyards, resulting in improved producibility, productivity and quality.

The second pre-contract planning meeting of the SP-4 Design Production Integration panel was sponsored by NNS in Atlanta on June 3, 4 and 5, 1981. Thirty-nine (39) participants representing 14 shipyards, the Ship Production Committee, Headquarters Naval Material Command, the Maritime Administration, 4 design agents, 2 universities, 2 consulting firms and an aerospace corporation worked to



# NATIONAL SHIPBUILDING RESEARCH PROGRAM INDUSTRY ORGANIZATION

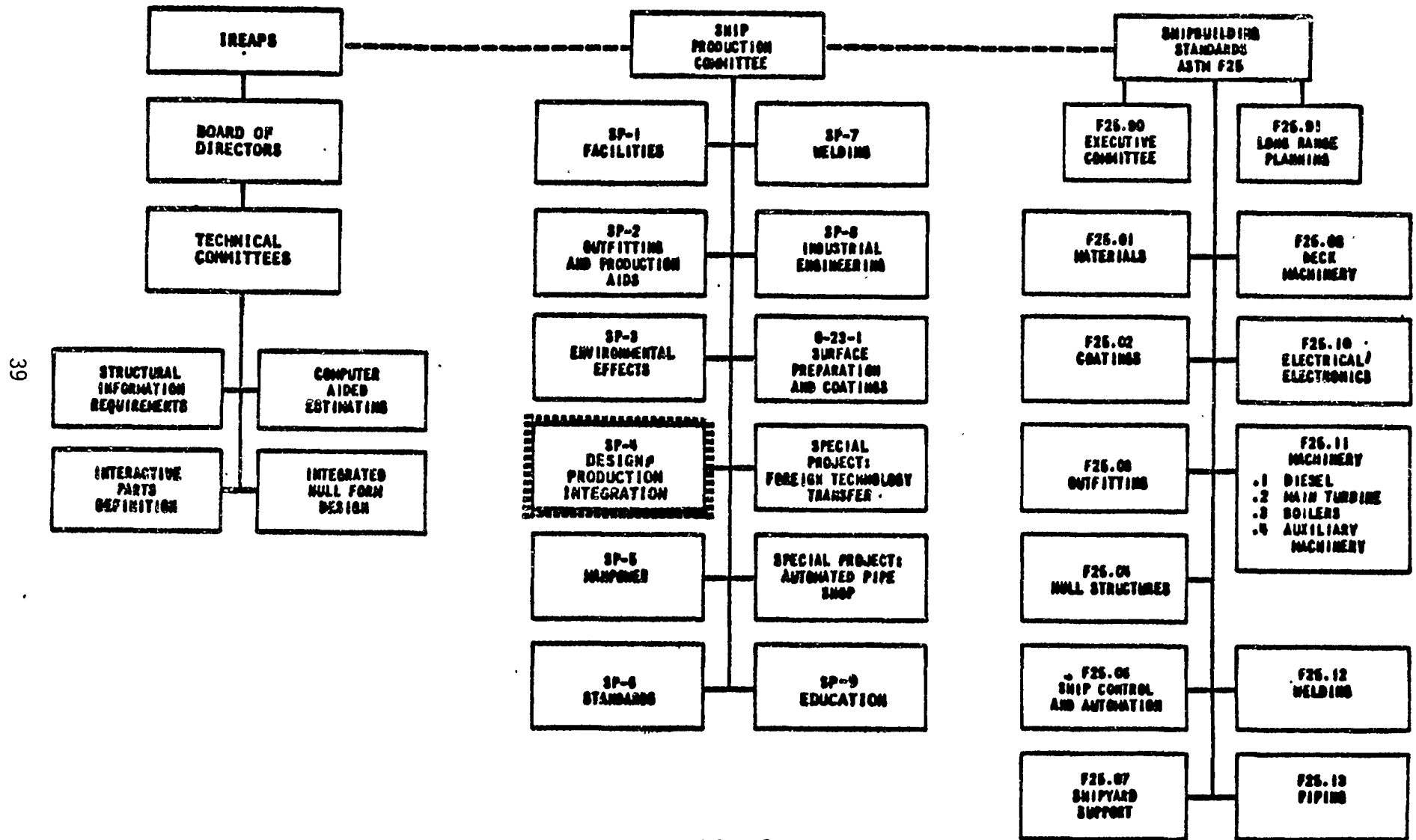


Fig. 2

develop a consensus program. The investment by the industry continues in order that all proposal and subcontract preliminaries may be accomplished prior to FY 1982 funding availability.

An outline of FY 1981 activity to-date is provided in Fig. 3.

#### SP-4 DESIGN PRODUCTION INTEGRATION

##### Summary of FY 1981 Actions To-Date

October 13-17, 1980	DPI concepts presented at SPC meeting, Philadelphia
January 18-21, 1981	Design Production Integration Workshop, Atlanta
February 25, 1981	Proceedings of Conference/Workshop transmitted
April 9-10, 1981	SPC Program Chairmen/Managers Meeting, Washington, D. C.  - FY 1981 funds not available - FY 1982 budget set at \$400 thousand
April 23-24, 1981	SPC established DPI and approved budget
June 3-5, 1981	Design Production Integration Planning Meeting, Atlanta

Fig. 3

### III. FY 1982 PANEL WORK PLAN

The FY 1982 plan was further developed at the June 1981 meeting in Atlanta. The work under the Design for Producibility Program has, by consensus agreement of the panel, been subdivided into projects. Each project has been scoped, assigned a tentative budget for the coming fiscal year and been undertaken by an industry project chairman.

The pre-contract investment by the industry continues to prepare the project work scopes and the subcontract proposals pending funding availability.

#### A. NNS Panel and Programs Management

The program/project management concept is well established at NNS and is supported by competent and dedicated purchasing and contracting departments in addition to financial controls and legal services.

The functional relationships of the panel are depicted in chart form on Fig. 4.

NNS, as the lead yard, will:

- (1) provide a program management team to conduct the business of the panel. The program management function will consist of a panel chairman and an SPC program manager.

SNAME/SPC PANEL  
ON SHIPBUILDING  
DESIGN+PRODUCTION INTEGRATION  
SP-4  
FUNCTIONAL RELATIONSHIP CHART

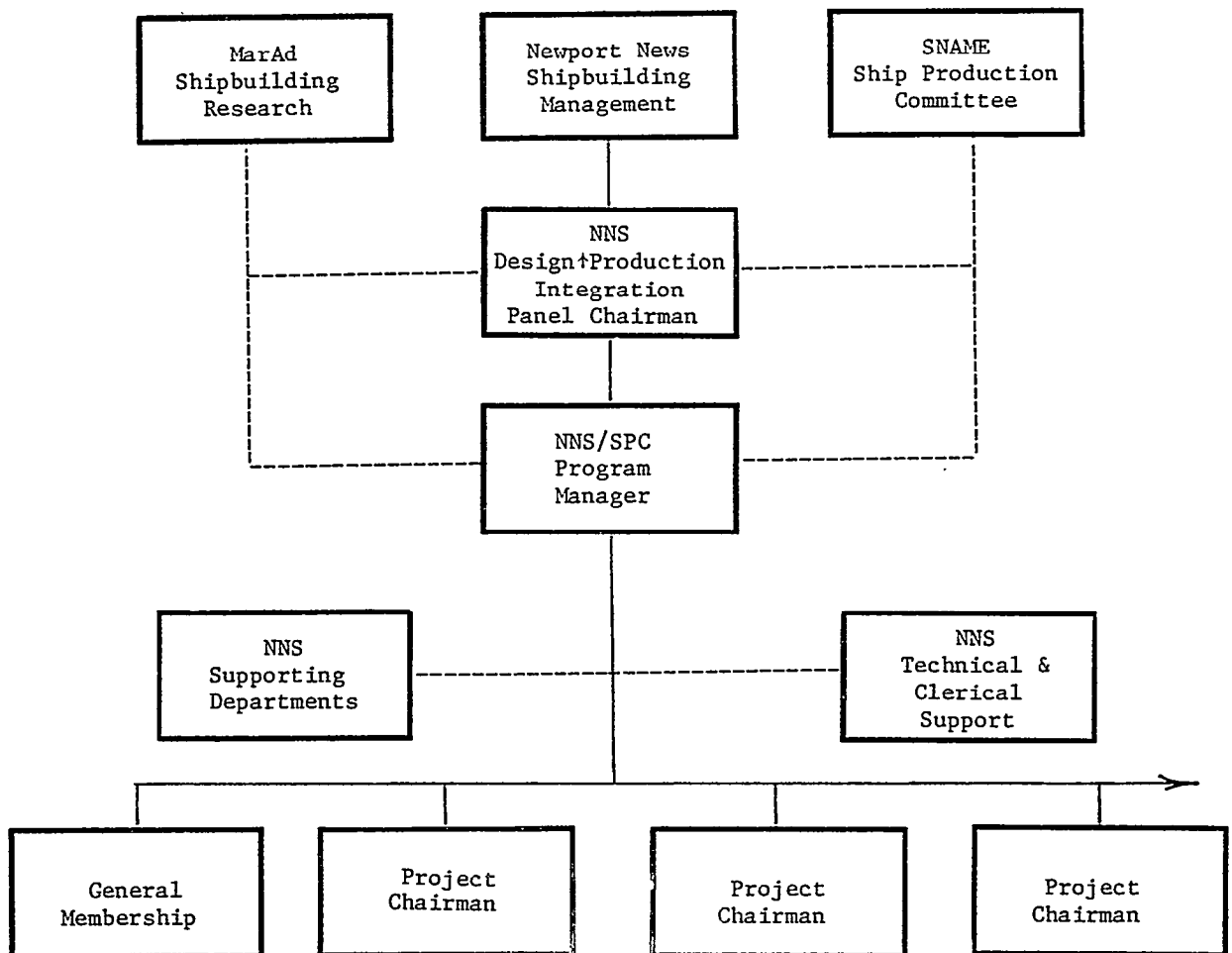


Fig. 4

- (2) convene regular panel meetings approximately four times a year or on a quarterly basis.
- (3) conduct program and project meetings as the relevant business demands.
- (4) work to obtain consensus agreement as to the nature and priorities of the panel's work.
- (5) undertake to subcontract work in the pursuit of the agreed upon scope of work of the panel, all in accordance with the terms of the contract including approvals as required.
- (6) assess performance of work in progress including on-site investigation as the need dictates.
- (7) submit monthly financial reports, formal quarterly progress reports and submit, or cause to be submitted, such other oral and written reports as required by the contract and subcontracts or as needed to further the business and mutual interests of the government departments, the Ship Production Committee and the panel.
- (8) cause final reports to be prepared, submitted and distributed at the completion of each project including projected cost benefits as a result of the project completion.
- (9) develop, in conjunction with the panel members and others, on-going projects of promising productivity improvement for the benefit of the shipbuilding industry as applicable on an industry-wide basis.

- (10) develop suitable and timely budgets for the panel's work within the constraints of funding and implementation capability.

The panel planning meeting provided sufficient project definition and scope to permit project chairmen to be identified and a tentative budget to be assigned to the projects. The project chairmen are now working to further define and refine the projects within the outlines provided. The objectives, technical approach, deliverables, benefits cost and schedule information are to be submitted. A target date of September 15, 1981 for completion of the technical and cost proposals has been set by the panel.

#### B. Projects

The following projects have been identified for FY 1982 (Fig. 5).

1. Design for Production Methodology - Two projects and one non-project have been identified as part of this task.
  - a. Project: Design for Production Manual  
Chairman: R. Ralph, Bethlehem Steel
  - b. Project: Design for Production Briefing  
Chairman: A. Kurzenhauser, St. Louis Ship  
Non-Project: Owner/Designer/Vendor Practices  
Liaison with SP-6/ASTM F-25  
S. Bailey, Avondale

SP-4 DESIGN PRODUCTION INTEGRATION  
FY 1982 PLANNED PROJECTS SUMMARY

		<u>Chairman</u>
A. Panel and Programs Management	\$ 83K	T. J. O'Donohue, NNS
B. Projects		
1. Design for Production Methodology		
a. Design for Production Manual	\$100K	R. Ralph, Bethlehem Steel
b. Design for Production Briefing	\$ 35K	A. Kurzenhauser, St. Louis Ship
2. Central Planning		
a. Engineering Change Control	\$ 90K	N. Monk, NNS
3. Classification/Regulatory Interface	\$ 10K	R. Ralph, Bethlehem Steel
4. Contingency	\$ 82K	
a. Defined Projects Being Developed		
b. New Projects		
c. Follow-on Projects		
Total	\$400K	

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Fig. 5

2. Central Planning - One FY 1982 project and several contingency projects have been identified.

a. Project: Engineering Change Control

Chairman: N. Monk, NNS

3. Project: Regulatory Body Approvals

Chairman: R. Ralph, Bethlehem Steel

4. Contingency

The following subjects were assessed for FY 1982 projects. Due to pending work by other panels or projects, action has been tabled at this time.

- Central Planning Manual = f (Design for Production Manual)

- Accuracy Control = f (SP-2 Publication)

- Standard Nomenclature = f (SP-9)



#### IV. SUPPLEMENTAL WORK PLAN

One of the highlights of the Design Production Integration Workshop held in Atlanta in January 1981 was a presentation by Mr. Paul Wiedenhaefer, entitled, "The Engineering/Production Integration Process: Graphics, Interactive Computing and Data Base."

The subsequent budget allocation of \$400 thousand for FY 1982 seemingly precluded any CAD/CAM efforts by the panel.

The exchange of information at the Design Production panels at the January 1981 meeting, and at subsequent meetings, revealed the U. S. Navy's rightful interests and concerns in the vital ship design/production relationships and the integrally related computer aided design/computer aided manufacturing aspects of that relationship.

Key representatives of NavMat and NavSea participated in the April, 1981 meetings of the SPC Program Chairmen/Managers in Washington, D. C. and the executive meeting of the SPC in New Orleans at which the Design Production Integration panel was duly established. Headquarters, NavMat was also strongly represented at the June, 1981 planning meeting of the Design Production Integration panel in Atlanta. The Department of the Navy's expressed intent to participate as a full partner and leader in the work of the Ship Production Committee and the SPC Design Production Integration panel was reiterated at the June meeting.

Mr. William F. Holden, Headquarters, Naval Material Command, gave presentations on the Navy Manufacturing Technology and the Navy CAD/CAM programs on the opening day of the June 1981 planning meeting of the Design Production Integration panel. Responding to Mr. Holden's invitation, a planning group for CAD/CAM was chaired by Mr. David V. Pearson, President of IREAPS. (Note that Mr. Pearson's name has been substituted for Mr. James R. Vander Schaaf, former IREAPS Program Manager and a participant in the planning group, in the following.)

Five CAD/CAM projects were identified for FY 1982 action and are presented in order of priority. Additional longer term projects were identified but not assigned.

1. Project: Functional Requirements Definition  
Chairman: F. Helming, SofTech  
Budget: \$50
2. Project: Initial Graphics Exchange Specification (IGES)  
for Shipbuilding Data Transmission  
Chairman: D. Pearson, IREAPS  
Budget: \$100
3. Project: CAD/CAM Survey
  - Shipbuilding Industry
    - . National
    - . International
  - Other U. S. IndustryChairman: D. Pearson, IREAPS  
Budget: \$200

4. Project: Group Technology Including Part Classification and Coding

Chairman: F. Posthumus, Todd-Seattle

Budget: \$150

5. Project: Research Standard Software Tools

Chairman: R. Skirkani ch, Grumman

Budget: \$75

0 Non-Projects

- CAD/CAM Technology Forecast
- Common Data Base/Data Element (DDS)
- Integration Methodologies
- "Shipyards of the Future"
- Simulation and Modeling Technologies
- Decision Support Software
- Assembly Sequencing

v. BENEFITS OBJECTIVE

The objective of the Design Production Integration panel work is directed toward lower overall shipbuilding costs, better quality, and reduced design and construction time between contract award and ship delivery.

The premise of the panel's work is that the initial planning and design actions are the predominant determinants of the final cost, duration of design and construction time and the quality of the

delivered product. The panel is dedicating its efforts to identify the major opportunities and applications of improved technology and methods based upon this important premise.

The work of the panel is to accept the challenges identified as project tasks for industry-wide solutions. The panel is action-oriented toward cost and time reduction with quality improvement through technology, producibility and productivity improvements of the planning, design and production systems with due emphasis on CAD/CAM.

Each proposed project under the panel programs will need to be justified with respect to anticipated benefits for consensus approval of the panel.

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## Appendix A

### References: Panel Publications

- . Proceedings of the Shipbuilding Design Production Integration Workshop, January 18-21, 1981. Volumes I and II, transmitted February 25, 1981.
- . Technical and Budget Proposal for Fiscal Year 1982 generated at the Planning Meeting of June 3-5, 1981, dated June 22, 1981.

## SP-6 - NATIONAL SHIPBUILDING STANDARDS PROGRAM

Samuel Wolkow  
Project Engineer  
Ship Producibility Research Program  
Bath Iron Works Corporation  
Bath, Maine

This paper will attempt to describe the events that have transpired in the Ship Producibility Research Program since the last report which was given at the REAPS Symposium in October 1980.

### PROGRESS HIGHLIGHTS

Since October 1980, SNAME Panel SP-6 met twice; once in February 1981 in San Diego, and the second time in June 1981 in Baltimore. ASTM Committee F-25 also had two regular meetings scheduled; the first one was held in Orlando in December 1980, and the second in May 1981 in Philadelphia.

During the past year, membership in SNAME Panel SP-6 has increased from nine to nineteen active organizational members, including the following new participating shipyards: Bay Shipbuilding, General Dynamics/Electric Boat Co, Ingalls, Lockheed, Marinette Marine, Peterson Builders, and Tacoma Boatbuilding. Voluntary representation on ASTM Committee F-25 on Shipbuilding has increased by 15% (to 175 official members) and continues to show a rising trend in membership status as the standards program achieves greater industrywide acceptance.

At this time, some 70 new shipbuilding standards are being developed under the program involving the activities of SP-6/F-25. Twelve of these are essentially complete, and seven have been formally adopted as ASTM/National Standards. Most significantly, a documented 83% of these new standards have been implemented in new shipbuilding contracts, resulting in an immediate multiple payback situation relative to the initial R&D investment. Several shipyards are now involved in new or expanded internal standards programs,

particularly in cases where advanced shipbuilding techniques such as on-block/on-unit outfitting, accuracy control, etc., are being applied.

U.S. Navy support of, and participation in, the standards program has become even more pronounced in the past year, notably through the efforts of RAdm E. J. Otth, Naval Sea Systems Command, Deputy for Acquisition and Vice-Chairman of Committee F-25, up to his retirement in June 1981. His successor as Deputy for Acquisition at NAVSEA, RAdm J. W. Lisanby, has indicated his intention to provide the same degree of involvement and participation. RAdm Otth's replacement as Vice-Chairman of Committee F-25 is RAdm T. M. Hopkins, who is currently the Naval Sea Systems Command Deputy Commander for Ship Systems. The first ASTM shipbuilding standard has already been incorporated in the Navy GENSPECS, and formal procedures have been established to ensure ongoing Navy assessment of these commercial standards for Navy use. This trend toward cooperative standardization is expected to continue and even increase.

In summary, a year ago it was observed that the standards program was about to enter the second phase of evolution following the 1977/1978 implementation. At this point it is fair to state that this effort has successfully overcome initial resistance and start-up problems, and is recognized as an essential component of the current shipbuilding technology/productivity improvement thrust. By the end of this year, a formal long-range plan for shipbuilding standardization will be published, outlining specific priorities for both industrywide and individual shipyard programs.

#### CURRENT PROGRAM STATUS

The current status of SP-6 MarAd funded projects is summarized in Table 1.

#### SNAME PANEL SP-6 FY-82 PROGRAM RECOMMENDATIONS

The FY-82 Standards and Specifications program recommendation represents the consensus priorities of the SP-6 members as determined at the February 1981 meeting and reaffirmed as to specific subcontract accomplishment at the June 1981 meeting. Two-thirds of the proposed efforts are being undertaken by new SP-6 members participating in such work for the first time.

The FY-82 project recommendations listed below are intended to support ongoing progress in the standards program and provide a bridge to implement

projects in new areas based on known priorities and anticipated recommendations of the U.S. Shipbuilding Standards Long Range Plan. Two of the FY-82 projects will be funded at a later time using FY-81 special funds and reallocating budget underruns on completed work.

TABLE 1

<u>Project Title</u>	<u>Objective</u>	<u>Status/Comments</u>
Shaft Alignment Standards	Develop standard procedures and documentation for: (1) geared steam turbine, inboard shafting; (2) diesel, outboard shafting; and (3) geared steam turbine; outboard shafting.	Complete and in ASTM review
Weld Defect Tolerance Study	Develop rationale for reduced rework/repair through engineered standards.	Complete. Commercial report published 6/1/80. Navy report published 3/81. Follow-up planned.
Mechanical Design/Construction Stds. - Groups I & II	Develop initial standards for common items.	Complete Many items already in use.
HVAC Design/Construction Standards	Develop initial standards for common details.	70% complete
Outfit Design/Construction Standards	Develop initial standards for common items.	60% complete
Standard Specification for Piping Systems	Update and revise MarAd Standard Schedule (2-69)	10% complete. Limited effort to date.
Shipbuilding Standards Long Range Plan	Development of clear program priorities.	Contract signed w/IHI Marine Technology 3/81 & will complete 12/81.
Mechanical Design/Construction Stds. - Group III	Development of standards for additional common items.	Work started 7/81
QA/QC Acceptance Standards	Identification/development of priority cost saving standards.	Work started 5/81.

1. Plan Submittal/Approval Cycle

Development of this task is tentatively being deferred pending issuance of a USCG NVC intended to implement a memorandum of understanding between the USCG and ABS covering transfer of certain design and inspection functions from CG to ABS. The effective date of the NVC was targeted for August 1, 1981.

2. Standards Program Sound/Slide Documentary

This is intended to be a 15-minute presentation of the standards program in general and the long range plan in particular to promote industrywide support and participation. The documentary could be made available throughout the industry to promote and publicize the scope, goals and accomplishments of the standards program and to emphasize the actual and projected benefits which can result.

The following projects were recommended by Panel SP-6 for FY-82 funding:

1. Standardized Purchase Inquiry & Bid Response Sheets

Tacoma Boatbuilding Co. has submitted a proposal defining the scope of work necessary to accomplish this task. Basically, this project is intended to provide standardized parameters for defining operating and performance characteristics of main and auxiliary equipment and for developing a standard format for the review and evaluation of bid responses.

2. Mechanical Design/Construction Standards - Group IV

Bath Iron Works will continue development of a comprehensive set of standards for commonly used items such as foam and fire station cabinets, standard thermometer selection chart, standard gage selection chart, shot blast procedure for descaling the interior of steel pipe, strainers, flanges, striker plates, and flanged tube ends.

3. Navy GENSPEC Review

John J. McMullen Associates has submitted a proposal to conduct a professional review of NAVSEA 0902-001-5000, "General Specifications for Ships of the U.S. Navy". The purpose of this review will be to identify specific priority areas where naval and commercial standards/specifications can be improved, consolidated, or interchanged.



#### 4. Functional Design Standards

John J. McMullen Associates has also submitted a proposal to develop functional standard drawings for subsystem components which should result in production capability improvement through utilization of zone outfitting and outfit package concepts which are non-shipyard unique. Four subsystems are included in this initial effort. They include: multistage flash distilling plant; geared steam turbine lube oil unit; fuel oil service unit; and ships service air compressor unit.

#### 5. Long-Range Plan Implementation - Phase I

This project is intended to provide immediate funding for implementation of high priority recommendations resulting from the U.S. Shipbuilding Standards Program Long Range Plan in advance of FY-83.

#### 6. Hull Design/Construction Standards - Group II

This task was intended to develop a second set of standards for commonly used hull items such as: watertight life jacket stowage lockers, fire station arrangements, deck stands, floodlight foundations, and ductwork penetration details, among other candidate priority items.

#### 7. Special Development Project Funding

To provide funding for short term, high priority special efforts such as studies, workshops, consulting services, etc.

### ASTM COMMITTEE F-25 UPDATE

As previously stated, the fifth regular meeting of Committee F-25 was held in May 1981 in Philadelphia. The special feature of this meeting was a workshop which was organized to provide a forum for the Vendor/Supplier community to address the problem of improving the marine equipment supplier productive capability and developing industrial standards to reduce shipbuilding costs and schedule durations for simplifying procurement and design submittal procedures; and for assuring greater reliability and maintainability of subcontractor's products.

The motivation for this workshop was the concern of many owners and operators of merchant marine and particularly naval vessels over difficulties they were experiencing in obtaining major and auxiliary machinery components

to adequately support ship construction, operation, and maintenance requirements, with the degree of reliability and continuity upon which the shipbuilding industry depends.

Fleet operators are alarmed at the apparent erosion of the Vendor/Supplier industrial base. This is of special interest to the Navy Department, whose plans for extensive fleet expansion can be seriously jeopardized by excessive costs of subcontractors' products affecting the affordability of ships.

Ninety-four industry representatives from over forty major equipment supplier and manufacturing companies attended the workshop. They heard nationally recognized experts from all sections of the shipbuilding industry discuss the marine equipment supplier problem from various perspectives. Later, the attendees met in special groups covering the following categories:

- Main and Auxiliary Propulsion Systems
- Electrical/Electronic Equipment
- Hull Mechanical/Deck Machinery
- Regulations/Administrative Requirements

In general, the following topics were among the major problems discussed:

1. The need to simplify purchasing and plan approval procedures.
2. The need to reduce manufacturing lead times for critically needed equipment.
3. The need to establish multi-year procurement practices to ensure a vibrant, constant market for equipment suppliers,
4. The need to develop commercially oriented GENSPECS to minimize the dependence on military or federal material specifications.
5. The need to establish a uniform standard identification system for spare parts replacement, especially for equipment from other than the original manufacturer.
6. The need to provide definitive performance criteria and operational characteristics in purchase specifications.
7. The need to discourage continual re-design of frequently used equipments which have proven satisfactory service experience under operating conditions.
8. The crucial need to improve the adversary relationship between producer, builder, and owner.

## WORKSHOP CONCLUSIONS

As was to be expected, both favorable and negative comments resulted from the working sessions. At the plenary session held on the second day of the workshop, the following general observations were expressed:

1. The need for greater accountability, reliability, producibility, and maintainability of subcontractors' products.
2. The need to develop effective procedures for productivity management.
3. The need to reduce government regulations.
4. The need to establish inducements or initiatives to encourage vendor/supplier involvement in developing industry standards.
5. The need to improve government/industry interface problems.
6. The need to study the impact of standards implementation on new contracts.
7. The problem of addressing preventative measures in liability for subcontractors.

Favorable comments originating from the working sessions included the following:

1. Builders/Owners want to avoid using costly custom designed equipment.
2. The desire of all interested parties to restore the competitive position of the U.S. shipbuilding industry.
3. The use of different materials for identical components clutters and complicates the supply system.
4. Working within the ASTM organizational structure ensures a program of periodic review, maintenance and updating of all standards.

Critical comments against the Vendor/Supplier community's participation in the standards program included:

1. Industry prefers to use existing standards as much as possible.
2. Existing industry standards could be used if government requirements were relaxed.

3. There are a sufficient number of applicable industry standards currently available to satisfy users' requirements.
4. Dimensional standards are too limiting and restrictive for the marine equipment supplier industry.
5. Standards such as the IHI (JIS) specifications are too detailed.
6. Equipment suppliers are worried about antitrust actions.
7. Concerns about the government's (Navy) commitment to use commercial standards.

In summary, the workshop's stated objective of enlisting industry support to develop an integrated approach to the National Shipbuilding Standards Program was considered productive. It was the consensus of the workshop participants that if the U.S. Shipbuilding Industry is to achieve productivity equality with foreign shipyards, standardization of subcontractor's products will be an essential component for improving the industry's competitiveness in world markets.

#### FUTURE PLANS

The Vendor/Supplier workshop was the third in a series of such conferences organized by Committee F-25. The first two involved the Shipbuilders and Owner/Operators, respectively.

A fourth workshop for Naval Architects/Design Agents is being planned for the May 1982 meeting which will be held in Philadelphia.

The committee's sponsorship of these workshops is part of an innovative program to draw previously uninvolved owners, builders, suppliers and designers into the standards program to achieve a truly integrated industrywide effort in this endeavor.

Thank you.

## SP-8 - SHIPBUILDING INDUSTRIAL ENGINEERING PROGRAM

Joseph R. Fortin  
Project Engineer  
Ship Producibility Research Engineer  
Bath Iron Works Corporation  
Bath, Maine

SNAME Panel SP-8 was established in 1978 to act as the shipbuilding industry's steering committee for a national industrial engineering effort. Presently, the panel's 18 members represent both large and small U.S. shipyards. The panel is also supported by members of professional organizations and academia, e.g., American Institute of Industrial Engineers, University of Massachusetts, Georgia Institute of Technology and others. Panel SP-8 is currently involved in Phase II of a multiphased program designed to increase productivity through the application of industrial engineering techniques.

### PHASE I

Briefly, Phase I of this program was implemented in late 1979 under the title "Shipyard Methods/Labor Standards Development Program". There were two primary goals established for this phase: (1) to improve methods and develop engineered standards, and (2) to increase shipyard management awareness of the potential benefits available through the use of basic industrial engineering techniques. Six shipyards actively participated in this program, received formal work measurement training, and began improving methods, creating engineered standards, and formally documenting their progress in the form of work management manuals. These manuals included standard practices and policies, equipment used, layout and material flow, manual methods used and other information supporting the engineered labor standard. Phase I produced 10 such manuals for publication and distribution through the industry in the following work areas:

- Pipe Shop
- Blast and Coat Shop
- Hull Erection
- Steel Shell Assembly
- Steel and Aluminum Small Assembly, Bulkheads, Webs
- Foundations
- Panel Line
- Panel Assembly on Platens
- . . . and two general shipyard manuals

Each of the six yards documented initial savings of between 15% to 40% in methods improvements alone during this first phase. Specific areas improved upon were shop layout, material flow, crane utilization, replacement of out-dated manual machinery with new, more efficient machinery, and many other somewhat obvious changes requiring minimal capital investment. In several of the yards, actual audited savings exceeded the initial R&D investment less than 1 year following project completion (noting that these improvements are cumulative, accrue immediately, and will apply to all future work).

The second primary goal of increasing shipyard management awareness of the potential benefits of using industrial engineering techniques was successfully accomplished by the presentation of 15 executive briefings to middle and upper shipyard managers throughout the country. These briefings, prepared and presented by the American Institute of Industrial Engineers for Panel SP-8, were extremely well received. To follow up these briefings, a series of Production Control Workshops, intended to acquaint these same shipyard managers with the benefits of standards application in the planning, scheduling and production control areas of the shipyard, were delivered to the majority of yards. This concluded Panel SP-8 Phase I activities.

## PHASE II

With Phase I successfully completed and a long range Industrial Engineering Program Plan in place, Panel SP-8 began Phase II of the Methods/Labor Standards Development Program in April of this year. Under the guidance of the Maritime Administration and with the consensus of Panel SP-8 membership, objectives for this Phase II effort were defined as:

- Continue methods improvements
- Continue standards development
- Continue education of shipyard personnel in I.E. techniques
- Define areas of shipyard standard data application
- Test and evaluate the computerized "MOST" (Maynard Operational Sequence Technique) System . . . the time measurement system being used to develop our engineered standards

Specifically, there are five shipyards actively participating in the funded portion of this program. A project team from each yard was formally trained in the use of the MOST Computer System and returned to their respective yards to apply this training in the development of engineered labor standards. Five new areas of the shipyard were selected for coverage during this phase. The yards and areas of involvement are:

- Bath Iron Works - Main Assembly Area
- Peterson Builders - Electrical Shop/Installation
- Newport News - Blast & Paint on the Dock and Platens
- Bethlehem Steel/Sparrows Point - Staging
- National Steel & Shipbuilding - Plate Shop

As in Phase I, each yard is responsible for thoroughly documenting all project activities and reporting their results to the panel. Continued savings are anticipated throughout this phase due to the implementation of improved methods and equipment.

Another important element in this phase of the program is the testing and evaluating of the MOST Computer System. Our approach has been to utilize this system as a group of users, maximizing the information available by cross-sharing and reducing the expense of computer time and storage. This will be explained in much greater detail by the H. B. Maynard & Co. consultant to our program, Mr. Lou Kuh.

The third and probably the most significant element of Phase II is the definition of how these standard data are to be applied in each yard. Prior to completion of this phase, each participating yard is expected to have identified and demonstrated on a trial basis, that application of engineered standards in their chosen area is feasible and cost effective. It should be

pointed out that utilization of standard data within each shipyard is not to be viewed as a revolutionary new technique. The concept is to simply use the accurate, quantitative data, developed and maintained by industrial engineers, to the maximum benefit of the shipyard.

In addition to the application of standard data for improving production methods and processes, several other functional applications are being considered. These are broken down into three basic functional areas:

1. Industrial/Manufacturing/Production Engineering
  - a. Methods improvement
  - b. Tool, equipment & machinery evaluation
  - c. Facility layout, flow & workplace arrangement
  - d. Productivity improvement, i.e., delay identification & elimination
  - e. Manload balancing - critical path determination
  - f. Labor incentive systems
  - g. Make/buy analysis
  - h. Long-range facilities planning
2. Production
  - a. Supervisory control
  - b. Manpower distribution & assignment
  - c. Labor performance reporting & analysis
  - d. Productivity improvement, i.e., identification of delays, interferences & inefficiencies.
3. Production Planning, Scheduling & Control
  - a. Labor budgeting
  - b. Shop scheduling
  - c. Critical path development
  - d. Material requirements planning
  - e. Group technology (process lane) planning
  - f. Estimating

Another new area being addressed as a special project during Phase II is the development and presentation of a formal Methods Engineering Training Program. Designed to be an intensive, 5-day workshop to train shipyard



representatives as instructors in basic Methods Engineering, the American Institute of Industrial Engineers is putting together a thorough training package, tailored exclusively to shipyard application. Upon completing this course, the trained instructor will have all the basic knowledge and materials necessary to establish an in-house Methods Engineering Program.

### PHASE III AND BEYOND

In 1982, Panel SP-8 efforts will be primarily focused on standard data application. A more detailed look at Methods Engineering and Material Planning and Control will also be on the agenda for action items. As progress is made and results documented, the panel will move into the more advanced industrial engineering aspects, i.e., group technology, information systems, operations research, etc.

### CONCLUSION

Panel SP-8 on Industrial Engineering is and has every right to be proud of their accomplishments to date.

## SP-7 - SHIPYARD WELDING

B. C. Howser  
Newport News Shipbuilding  
Newport News, Virginia

### ABSTRACT

The Welding Panel SP-7 was formed in recognition of the fact that reduction in welding time and improvement of welding quality would reduce the cost of building ships and allow U.S. shipbuilders to remain competitive in the world market. The panel provides opportunities for member organizations to propose and implement projects which examine existing welding technology for improvement and adaptation to shipbuilding and research and development of new technology which advances the state of the art in shipbuilding welding.

Currently, active projects include 'Visual Inspection Standards for Welds Not Requiring Other Inspection', 'Robotics in Shipbuilding', and 'Shielded Metal Arc Welding Against Ceramic Backing'. Proposed projects include 'Multiconsumable Guide Electro-slag Welding', 'Aluminum Welding in Shipbuilding', and 'Fitting and Fairing Devices'.



Hello!- I am B.C. Howser of Newport News Shipbuilding and I am Chairman Elect of the SNAME SP-7 Welding Panel. Over the next few minutes I would like to bring you up to date on the WHAT, WHY, WHO and HOW'S of the SP-7 Welding Panel. Contrary to what you might have been led to believe, because of someone's comments or because of the panel's recent management inactivity, SP-7 is alive and well. The inactive status has been the result of the time required to transfer the panel management from Sun Ship, Inc. to Newport News Shipbuilding. This has involved the lawyers, contract administrators and bean counters of three organizations - Sun Ship, Newport News and MARAD and as they all have told me on many occasions "THESE THINGS TAKE TIME!"

What is the SP-7 Panel? Why does it exist?

The SP-7 Panel is a productivity improvement panel whose membership is dedicated to the improvement and advancement of welding technology in U.S. Shipbuilding. It functions through joint industry - government (Maritime Administration) cooperation under sponsorship of the SNAME Ship Production Committee.

"Improve on the things we are  
currently doing and develop NEW  
and BETTER ways of performing  
in the FUTURE while maintaining or  
improving quality, "

Less Cost

No other US industry is as heavily committed to the welding process as is shipbuilding. The welding activity and its support functions represents a large (if not the largest) direct labor cost within a shipyard. It is therefore considered essential that the objectives of the SP-7 Welding Panel be directed toward support of projects which will reduce cost by improvement of existing processes, materials, techniques, and equipment and the development of new methods, materials and equipment which will decrease welding time while maintaining or improving weld quality.

## Who is the SP-7 Welding Panel?

The Panel currently has 23 members who represent many different organizations that are in some way involved with welding in shipbuilding; these organizations are as follows:

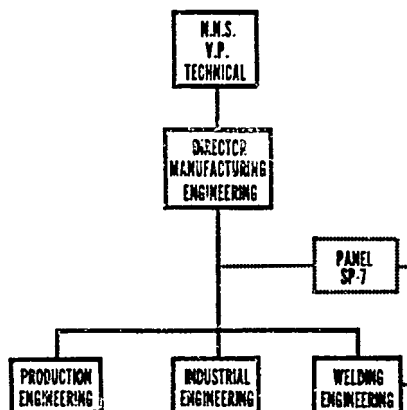
### **MEMBER ORGANIZATIONS SP-7**

AMERICAN BUREAU OF SHIPPING	INGALLS SHIPBLDG.	NORFOLK NAVAL SHIPYARD
AVONDALE SHIPYARDS INC	LEVINGSTON SHIPBLDG.	NORFOLK SHIPBLDG
BATH IRON WORKS	MARITIME ADMINISTRATION	OFFSHORE POWER SYSTEMS
BAY SHIPBLDG. CORP.	NATIONAL STEEL & SHIPBLDG.	PETERSON BUILDERS
BETHLEHEM STEEL-SHIPBLDG.	NAVSEA	SUN SHIP
GENERAL DYNAMICS SHIPBLDG.	NEWPORT NEWS SHIPBLDG.	TODD SHIPBLDG. CORP.
U. S. COAST GUARD		

Membership is selected by the panel and anyone here today who feels they are directly involved with welding in shipbuilding is invited to submit their name to the group for consideration.

Under the current contract with Newport News Shipbuilding the management of SP-7 is performed by B.C. Howser, Panel Chairman and M.I. Tanner, Project Manager, who together bring to the panel 50 years in welding experience and management.

### **SP-7 MANAGEMENT**



As you can see, panel management is directly responsible to the Director of Manufacturing Engineering, who also has Welding Engineering, Industrial Engineering and Production Engineering reporting to him who in turn reports to the Vice President, Technical. These individuals along with other top management officials of our company have pledged full support to the activities of the SP-7 Welding Panel.

#### How does a project get implemented?

Future projects which are submitted by member and interested non-member organizations are reviewed and selected by vote of the panel membership. After approval by the panel the organization which has submitted the proposal will then enter into a sub-contract agreement with Newport News Shipbuilding for funding of the project.

As previously stated, Newport News has taken over the management of a program previously implemented by Sun Ship, Inc. There are six (6) specific projects which have been identified, four (4) of which have been sub-contracted and two (2) which have not yet been formally committed.

#### Current Projects

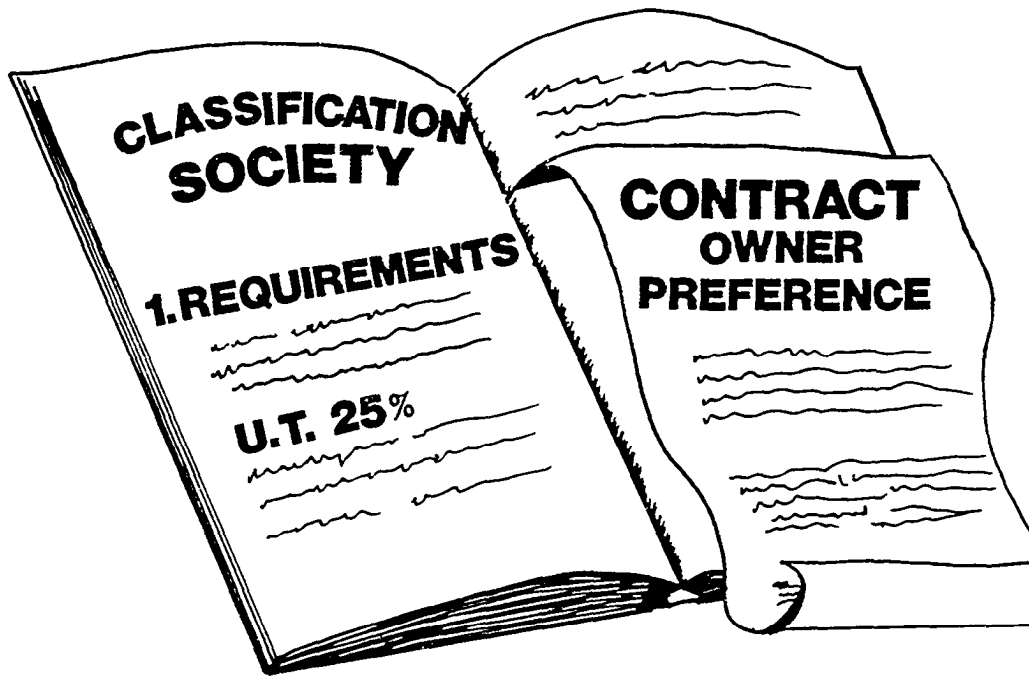
##### CURRENT PROJECTS

- ACCEPTANCE STANDARDS FOR NONDESTRUCTIVE TEST NOT REQUIRED BY CLASSIFICATION
- PLASTIC WELD MODELS-VISUAL REFERENCE STANDARDS FOR WELD SURFACE APPEARANCE
- SHIELDED METAL ARC WELDING OVER CERAMIC BACKING
- CINCINNATI MILACRON T<sup>3</sup> ROBOT
- UNIMATION APPRENTICE ROBOT
- FITTING AND FAIRING DEVICES
- SPECIAL STUDIES

Acceptance Standards for Nondestructive Tests Not Required by Classification - Phase I - Ultrasonic Test - Sub-Contractor - American Bureau of Shipping

In new construction shipbuilding, ABS Rules for Nondestructive Inspection of Hull Welds require ultrasonic tests for full penetration welds in the midship such as intersections of butts and seams in the bilge strakes, sheer strakes, deck stringer and keel plates and butts in and around hatch corners. These required inspections have specified well defined acceptance standards. Other

inspections are sometimes performed for shipyard internal quality control and to satisfy contractual agreement for owner requested inspection. These inspections, which are beyond classification society requirements, do not have established acceptance standards.



The objective of this project is to establish guidelines to determine at what point weld defect indications in full penetration welds are considered insignificant or at what level the indication could cause the structure to be unreliable.

Plastic Welding Models - Visual Reference Standards for Weld Surface Appearance - Sub-Contractor - American Bureau of Shipping



**VISUAL INSPECTION WELD SAMPLES**

Written acceptance criteria for visual inspection of welds in the shipbuilding industry have proven too vague to avoid differences in interpretation and the members of the SP-7 panel expressed a need for more specific visual reference standards.

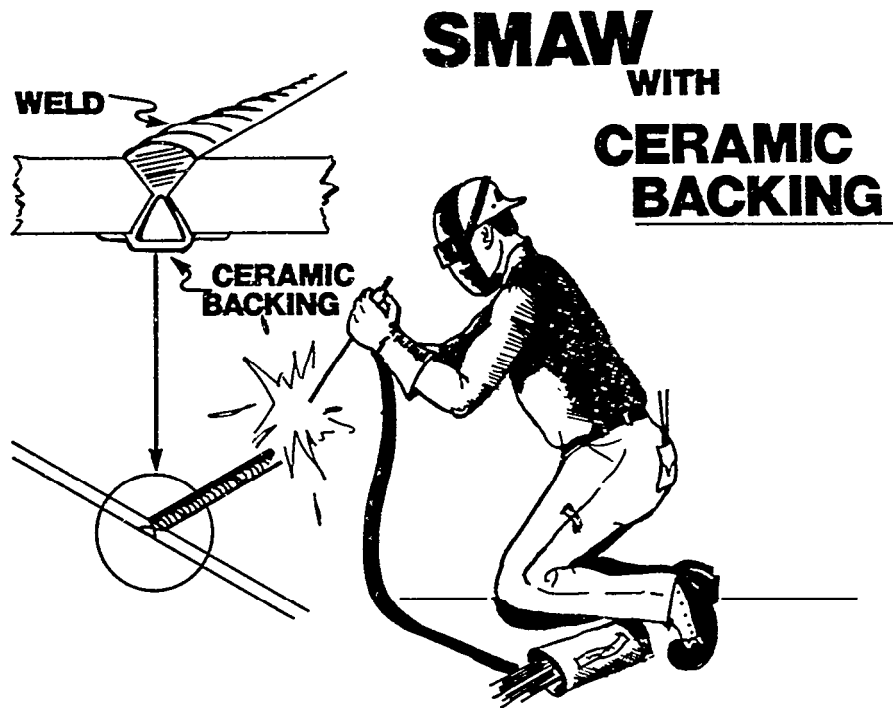


## VISUAL INSPECTION WELD SAMPLES

The objective of this project is to obtain weld samples containing various levels of surface roughness, undercut, porosity, overlap, etc. which would serve as the basis for the manufacture of plastic models which could be made available as reference standards for use by shipyards, shipowners and inspection personnel.

Shielded Metal Arc Welding (SMAW) Over Ceramic Backing - Sub-contractor - Offshore Power Systems

The use of ceramic tile backing in conjunction with shielded metal arc welding continues to increase due to its ease of application and economic advantages. In the developing technology, new and improved equipment and products have entered the market place. Refinements in techniques and application have become so sophisticated that one manufacturer markets a complete ceramic system comprised of ceramic tiles, specially formulated low slagging electrodes and ultra-hot-start alternating current welding systems.

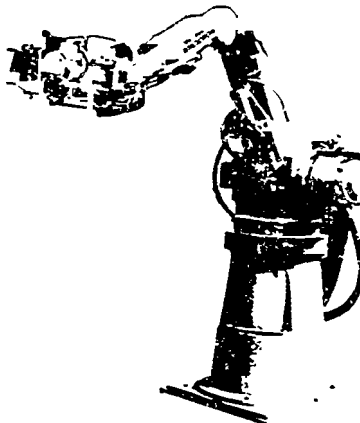


The objective of this project is to perform a state of the art evaluation of the techniques, equipment and parameters to SMAW over ceramic tiles. The evaluation will include a number of different brands of tiles, including one foreign brand which will be evaluated along with magnetic and adhesive backing systems.

Industrial robots are used throughout the world in manufacturing operations that are monotonous and boring, too hazardous and in some cases, uneconomical for humans. One of the most promising areas for development today lies in adapting industrial robots to shipbuilding welding. This appears to be possible if the problem of consistent close tolerance fitup is solved, or if a system is developed that will precede the robot welder which will "read" the joint and make the necessary adjustments for varying fitups. The SP-7 panel has funding allocated for two robot projects:

Cincinnati Milacron T<sup>3</sup> Robot - Sub-Contractor - Todd Shipbuilding,  
Los Angeles

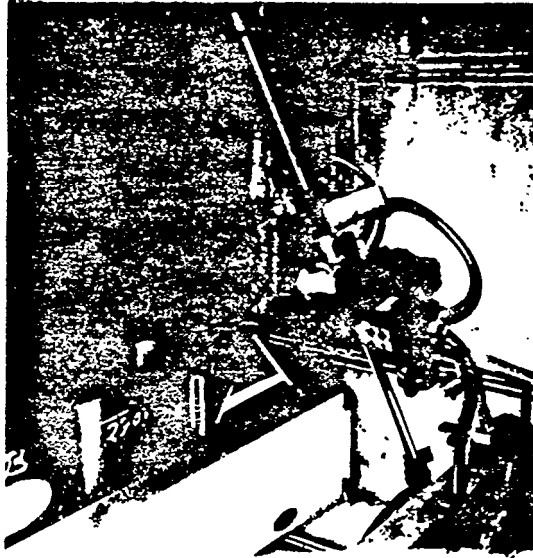
#### **CINCINNATI MILACRON T<sup>3</sup> ROBOT**





Funding has been allocated for the twelve month rental of a CMT<sup>3</sup> robot welder to evaluate its ability to perform repetitive welding jobs in a regular production environment. The T<sup>3</sup> is a stationary welding system which has the possibility of being applied to some of shipbuildings many shop welding jobs (pipe, hangers, collars, etc.).

Unimation Apprentice Robot Welder - Not committed

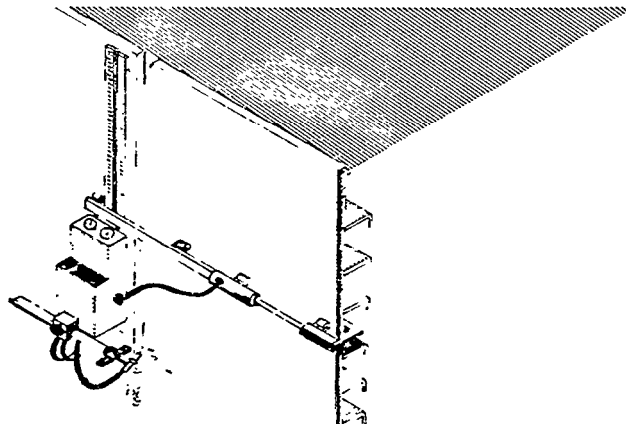


#### U N I M A T I O N   A P P R E N T I C E   R O B O T   W E L D E R

The Apprentice robot welder is identified as a portable welding system in that it can be taken to the work, rather than the stationary type which requires that the work be brought to it.

The objective of this project is to acquire an Apprentice robot welder, which has been done, and evaluate its performance in a shipyard, both under laboratory and production conditions, as to its dependability, ease of handling, positioning and productivity. At present, there is no sub-contractor for this project, but Ingalls Shipbuilding is very much interested in undertaking this task.

"Fitting and Fairing Devices" - Not committed



Successful automatic welding is dependent on consistent close tolerance fitup, which is generally not found in ship hull construction today, due in part to the lack of attention which has been given to fitting and fairing devices.

The objective of this project is to search for and/or develop fitting and fairing devices that can be used in conjunction with automatic welders and robot welders to provide the consistent fitup that they require. Avondale Shipyard, Inc., New Orleans, LA and National Steel and Shipbuilding Company, San Diego, CA have both expressed an interest in undertaking this project.

### Special Studies

This represents an account which contains funding that can be allocated to special projects which might develop during discussion at our panel meetings or submitted at sometime during the contract period.

### Future Projects

## **FUTURE PROJECTS**

### **1 ULTRASONIC TEST EQUIPMENT DEVELOPMENT**

- **ALUMINUM WELDING**
- **MULTI-CONSUMABLE GUIDE ELECTRO-SLAG WELDING**
- **TRACKING SYSTEM FOR ROBOTS**
- **MOLDABLE PADS FOR ONE SIDE WELDING**
- **SPECIAL STUDIES**

A request has been submitted for funding for the following projects:

#### Ultrasonic Testing Equipment Development

A project which will involve the use of electromagnetic acoustic transducers which are sensitive to horizontally polarized shear waves. It is predicted that this (NDE) method when developed could significantly improve the speed and reliability of ships' hull inspection.

## Aluminum Welding

Development of techniques and procedures which could minimize distortion of the aluminum base material during welding. This project would include but not be limited to investigation of heat input control, cooling rates, thickness requirements and welding sequence.

## Multi-Consumable Guide Electroslag Welding

The objective of this project is to develop the multiple consumable guide electroslag welding process/technique for joining 4" thru 24" thick carbon steel castings. Shipbuilding application of this process would be directed toward joining rudder arms, shafts, strut arms, shoe castings and other items which have not been feasible to cast in one piece.

## Tracking System for Robot Welding

The development of a tracking sensor, using infra-red light which would read variations in the joint fitup and transmit essential changes to the welding system. Such a tracking system appears to be the key factor for successful introduction of Robot welding in shipbuilding.

## Moldable Pads for One Side Welding

This project is to evaluate the feasibility of a "putty like" moldable pad which is a flux and wire composite designed to accommodate the high arc force associated with one side submerged arc welding. Successful results could significantly improve the productivity of one side welding by elimination of the gas metal arc (Mig) weld passes now being used to cushion the force of submerged arc welding.

## Special Studies

As previously stated this account is to provide funding for support of useful projects which might develop during the course of the contract period.

## Newport News Management Philosophy for SP-7 Panel

### NEWPORT NEWS MANAGEMENT PHILOSOPHY FOR SP-7 PANEL

#### • PROMOTE PRODUCTION EFFECTIVE PROJECTS

- ENCOURAGE TOTAL MEMBERSHIP PARTICIPATION
- SOLICIT SHORT AND INTERMEDIATE RANGE PROJECTS

#### • OBTAIN MAJORITY VOTE FOR PROJECT APPROVALS

1. COLLECT AND DISTRIBUTE ACCURATE DESCRIPTIVE AND TIMELY REPORTS

### Promote Production Effective Projects

Seek productivity improvement projects which will later be implemented in the shipbuilding fabrication industry and not just become the basis for a fancy bound report which will gather dust on the bookshelves of our technical libraries.

### Encourage Total Membership Participation

Assure that panel membership is submitting proposals, providing written response to panel correspondence and attending scheduled panel meetings.

### Solicit Short and Intermediate Range Projects

Obtain short range (less than one year) and intermediate range (two years or less) programs which can be defined, developed and utilized in shipbuilding production.

### Obtain Majority Vote for Project Approvals

The major responsibility of members of the SP-7 Panel is to define, approve, initiate and direct the welding research projects.

### Collect and Distribute Accurate, Descriptive and Timely Reports

Make sure that each report has the details of the development of each project which would permit the reader to implement its use and at the same time understand the advantages which would be realized.

## 0-23-1 - SURFACE PREPARATION AND COATINGS

John W. Peart  
Research & Development Program Director  
Avondale Shipyards Inc  
New Orleans, Louisiana

The keynote of this conference is INCREASED PRODUCTIVITY IN SHIPBUILDING.

With this thought foremost, I'd like to first "overview" the National Shipbuilding Research Program; and then discuss more specifically its recent efforts in the area of Surface Preparation and Coating.

The very first point I'd like to make about PRODUCTIVITY IN SHIPBUILDING, however, concerns a sea turtle.

Scientists at the Charles Darwin Research Station in the Galapagos Islands recently reported that a sea turtle had fallen in love with a rock! The scientists alleged that the turtle had been observed regularly, passionately attacking the rock (which, to some degree, resembled a sea turtle). That frustrated turtle seems in the grip of some profound learning experience that holds a couple of clear lessons:

Lesson 1 - Effort and results are not necessarily related; and

Lesson 2 - It is awfully important to be discriminating in one's choice of targets!

The American shipbuilding industry has recognized the turtle's first lesson: that intense applications of labor may not bring about effective and satisfying results -- and in fact "labor without logic" may merely waste man-hours. Giving careful attention to the necessary logic, the U.S. shipbuilding industry undertook a cost-shared Research & Development Program with the Maritime Administration to find more cost-effective ways to produce ships.

I believe the National Shipbuilding Research Program has mastered Lesson 2 as well. Since its inception, it has been careful and discriminating in its target selection from a wide range of possible areas for investigation and

implementation. Those targets that have been chosen, however, show a pattern of positive change, real results, and productivity improvement.

One factor important to the Program's success must be recognized: the participation in problem definition and program selection of the Society of Naval Architects and Marine Engineers' Ship Production Committee and its Subcommittees.

I refer specifically to the 023-1 subcommittee.

Although doubtless other program managers would say the same for their committees, shipyard participation and interest in this particular subcommittee, the 023-1, has been excellent; the attendance and contributions of the members have been outstanding. This means management sees the usefulness of the programs. Why is this so? Because the participants are accomplishing something more important than just program identification. They are also communicating with management, whose implementation of programs "in yard" has resulted in real cost savings.

With regard to the National Shipbuilding Research Program, I believe there's a general awareness of two facts which I'm going to mention anyway:

First: the Program is facing some budget constraints at the present time;

Second: the Department of the Navy -- recognizing the importance of higher shipbuilding productivity in building a stronger fleet -- is now participating in the National Shipbuilding Research Program, as well as initiating an active manufacturing technology program of its own.

This alliance is warmly welcomed.

Despite any rumors to the contrary, we shipbuilders have always shared two common interests with the Navy - ships and women.

We're now following those common interests with joint efforts: efforts to achieve desired results at lower cost, (where SHIPS are concerned, that is. I'm not sure what anybody can do about the cost of women.)

Any approach to cost-effectiveness in building ships must include Surface Preparation and Coating as one factor to take into account. Justified attention has been given this topic from the Program's beginning. Since

that time, however, there has been a changing emphasis indicating a growing sophistication of method, and maturity of approach.

The first Surface Preparation and Coating projects were basic methods-and-materials guides with a definite "how-to" emphasis; HANDBOOK OF SMALL TOOLS FOR BLASTERS AND PAINTERS, and SURFACE PREPARATION AND COATING OF SHIP TANKS.

These initial guides made clear, however, a need for personnel training, especially supervisory training, for blasting and painting operations. Subsequently, programs were set up to meet the indicated training needs, with good results.

We next became concerned about the climate of ever-increasing local and federal regulations and their possible cost impact on coating and blasting operations. This concern generated such reports as CITRIC ACID CLEANING and HIGH SOLIDS AND WATERBORNE COATING EVALUATIONS.

The importance of appropriate standards as a vital aid in lowering surface preparation and coating costs also became apparent, resulting in PRACTICAL SHIPBUILDING STANDARDS FOR PREPARATION AND COATING, and EDGE PREPARATION STANDARDS.

This brings us up to the present, when a high level of interest in Japanese shipbuilding technology is promising to have a large impact on our own "state of the art". Japan's emphasis on neglected areas such as Standards Establishment; Zone Planning; Materials Control; and Worker-Oriented (as opposed to Task-Structured) work systems -- all these give us new, international research avenues that could have a very high payoff. We are presently looking at Japanese surface preparation and coating operations to see how they compare in productivity to our own surface preparation and coating methods and practices.

#### CURRENT RESEARCH

I'd now like to comment on several interesting developments which have occurred as a result of our research efforts. One specific research focus has been on Abrasive Quality.

Various abrasives -- sand, steel grit, coal slag, etc. -- are used in surface preparation because of their relative effectiveness in cleaning a

surface prior to coating. A few variables, should be looked at, however. And a few cautionary notes apply.

In our investigation of citric acid cleaning, for example, an interesting sidelight occurred while blasting panels for coating application with various abrasives: rapid re-rusting of the coal slag abrasive-treated surfaces was noted. In fact:

- After 2 hours laboratory storage ambient conditions approximately 70°F 55% RH, the coal slag abrasive-blasted panels were already turning. (The grit-blasted and sand-blasted panels remained comparatively stable.)
- After 24 hours, surface oxidation on the coal slag abrasive-blasted panels was extensive (again contrasting to the more stable panels blasted with grit or sand). Subsequent testing of water leachings from the abrasives verified high chloride contamination. Investigation of the manufacturing process indicated that the power plant producing the raw material was quenching the slag in water with a high salt content.

As a direct result of these occurrences, a program was set up whereby abrasives are being investigated and evaluated by source, as well as on the basis of availability, quality, etc.

The results will be incorporated in an industry Abrasive Specification through ASTM Committee F25.02.

Wax-Based Semihard Coatings are another current research target.

Microcrystalline wax-based semihard coatings find successful use as tank coatings for water immersion service. They have the advantage of being able to be applied over light, tightly-adhered rust, additionally offering good blister-free corrosion protection when applied in sufficient thickness. Our program comparing the economics of these coatings with anodes, epoxy tank coatings, partial coatings with anodes and cathodic protection alone revealed that some of these are not compatible with cathodic protection.

Since failure was noted very quickly in additional tanks, it was decided that generic wax-based materials from two different supply sources be screen-tested. Screen-testing of the second of the two supplier's products displayed a mode of failure previously observed: coating failure due to spalling and lack of adhesion.



[NOTE. When ongoing research produces a direct dollar benefit--that's not really news. Research is supposed to pay for itself, after all: cash-effectiveness is its very dynamic. Still: The value of tests such as those described above had a dramatic impact on one major new construction yard holding production contracts specifying wax-based coatings in ballast tanks, with anodes. This yard was represented on subcommittee 023-1, however. Given early access to data emerging from the tests, this man alerted his yard in time to avert a coating process that seemed certain to bloom into massive, costly, multiple! coating failures! Instead--again benefitting from ongoing research, the yard circumvented a potentially serious problem by removing, or masking, the specified anodes.]

Also under study is Calcite Coating of Tanks.

We are all familiar with calcite coating as the white deposit seen on bare areas of underwater hulls, cathodic protected. The sight indicates a working system: the hull is being protected.

A similar coating is applied in water mains to protect them from corrosion by flowing a saturated calcium carbonate solution through them.

It became apparent that if this coating could be applied to salt water ballast tanks, it would provide a cost-effective means of corrosion control. Thus an investigation into the deposition parameters was begun.

The investigation was unable to apply an adequate calcite film under diffusion-limited quiescent conditions. Considering the large potential cost savings involved, further investigation is planned. Spray application; forced agitation; A/C current; and chemical additives are among methods to be explored.

The goal of the Zone Oriented Surface Preparation and Coating Process Planning program is to identify the differences in coating systems, process and planning methods between the Japanese and U.S. shipyards, and provide procedures for integrating cost-effective methods in U.S. shipyards. (This program has been subcontracted to IHI and Chugohu Marine Faint, Ltd.)

To provide finer definition of program objectives and method of information transfer, Gerald Soltz and I toured selected Japanese shipyards and blasting and coating contractors earlier this year. Dr. Soltz will be presenting some of his observations in some detail at another conference session -- one I personally think well worth attending.

*NOTE. A comprehensive report on Japanese Shipbuilding, which will expand on remarks given at this conference by Dr. Gerald Soltz and Mr. John Peart, should be available by late January 1982.*

*Those interested in receiving a copy of this report should contact: John W. Peart, R & D Program Manager, Avondale Shipyards, Inc., P. O. Box 50280, New Orleans, Louisiana 70150.*

On the same general subject, however, I'm going to limit myself to a few summary remarks in the time remaining.

I would consider the following to be among the most obvious Japanese shipbuilding "success factors":

1. Detail Planning and Integration with Ship Construction and Scheduling.

Surface preparation and coating are treated as equal in importance with hull construction and outfitting; and addressed in every phase of the ship construction sequence.

Pre-Contract Negotiations  
Engineering  
Cost Control  
Materials Control (paint quantity; need dates)  
Outfit Scheduling (on unit; on block; on board)  
Dry Docking.

2. Accurate Measurement and Documentation of Man-Hours and Materials.

Precise cost of labor and materials are determined and documented. This serves two purposes: first, it provides accurate data for cost estimation in future contracts; and, more importantly, if actual costs exceed estimated ones, a "flag is raised"; and a timely inquiry can uncover the causes responsible for escalating costs! (Lessons learned in this process of inquiry, by the way, should make cost overruns on future projects less likely!)

3. Selection of Paint Systems Compatible with Construction Methods and Schedules.

#### 4. Good Specification Definition.

Little is left for interpretation and argument. Application parameters and quality standards are defined.

It seems that I have just finished presenting another LIST -- in this case, a list of factors which seem relevant to the question of productivity.

We've heard a lot about productivity, certainly; we've heard numerous phrases describing it: worker-oriented phrases such as "quality circles", and systems-related terms such as zone planning and product/work structures.

But more basic than any of these (though perhaps including all of them), is an underlying goal I believe we all share. No matter what our specifics or specialties, I think that on a broad general level we share a notion of just what we'd like to achieve together; and that is, simply: the application of logic to this business of shipbuilding.

### NATIONAL SHIPBUILDING RESEARCH PROGRAM

#### PUBLISHED REPORTS

##### (1) Handbook Small Tools for Blasters and Painters

This report defines the principles required for efficient blasting and painting. Specialized cleaning methods from power tool cleaning to closed cycle blasting are discussed, equipment and facilities are described and cost reduction procedures are defined.

##### (2) Practical Shipbuilding Standards for Surface Preparation and Coatings

This effort developed: (1) proposed "Shipbuilding Standard for Surface Preparation and Coating" and (2) a "Standard Paint and Coating Product Data Sheet" and identified the need for a preconstruction conference between the shipyard production and technical sections, the owner representatives and the coating supplier.

##### (3) Marine Coating Performance for Different Ship Areas

A computer program was developed to compare the effectiveness of the different generic coatings in the different ship areas. The trends indicated by the program were supported by prefailure analysis test results.

(4) Cleaning of Steel Assemblies and Shipboard Touch-Up Using Citric Acid

This program confirmed the compatibility of citric acid cleaned surfaces with the present state of the art marine coatings; optimized the cleaning solution and procedure and confirmed the feasibility of a Phase II study.

(5) Shipyards Marking Methods

This program identified a marking material meeting the necessary requirements of a durability and overcoatability with marine top coats.

(6) Training Course for Blasters and Painters and Student Handbook

Thirty-six (36) shipyards have participated in the instructor training program.

(7) Standard Procedure for Determining Volume Solid

This program attempted to develop a procedure to determine the volume solids of liquid coatings based on a uniform film thickness measurement. It was unable to obtain accuracy and precision equivalent to the present ASTM procedure because of the inability of casting a uniform thick film. If the ASTM procedure is used, some heat must be applied to the curved film to obtain a constant weight. This temperature should be agreed with between supplier and purchaser if an accurate coverage rate is to be obtained.

8) Evaluation of Near Solventless Coatings

This program compared available near solvent free coatings with available "State of the Art" Marine Coatings. The coatings were exposed to testing conditions representative of the different ship areas. Many of the coatings performed as well as conventional systems but usage in certain ship areas would be limited because of application requirements and build characteristics.

(9) The Feasibility of Calcite Deposition in Ballast Tanks as a Method of Corrosion-Control

This program evaluated the parameters required for the deposition of thick calcite coatings on steel substrate from low concentration of colloidal calcium carbonate. This coating in conjunction with anodes would provide an economical means of corrosion protection in ballast tanks. Heavy coating deposition was obtained but solution agitation or flow was required. Phase I of the program will attempt to provide a practical method of initiation compatible with the complex configuration of ballast tanks.

REPORTS IN PUBLICATION

(1) Surface Preparation and Coating of Tanks in Closed Areas

(2) Survey of Existing and Promising New Methods of Surface Preparation

(3) Evaluation of Waterborne Coatings

#### PROGRAMS IN PROGRESS

- (1) Rust Compatible Primers
- (2) Cathodic/Partial Coatings vs. Complete Coating in Tanks
- (3) Comparison of Surface Profile Measuring Methods
- (4) Reclamation of Mineral Abrasives
- (5) Zone Planning of Surface Preparation and Coating
- (6) Abrasive Survey

#### PROGRAMS TO BE SUB-CONTRACTED

- (1) Edge Preparation Standard
- (2) Marine Coating Performance for Different Ship Areas - Phase I

\* If copies of reports are desired please contact:

J. W. Peart  
Program Manager  
Avondale Shipyards, Inc.  
P.O. Box 50280  
New Orleans, LA 70150  
504/436-5314

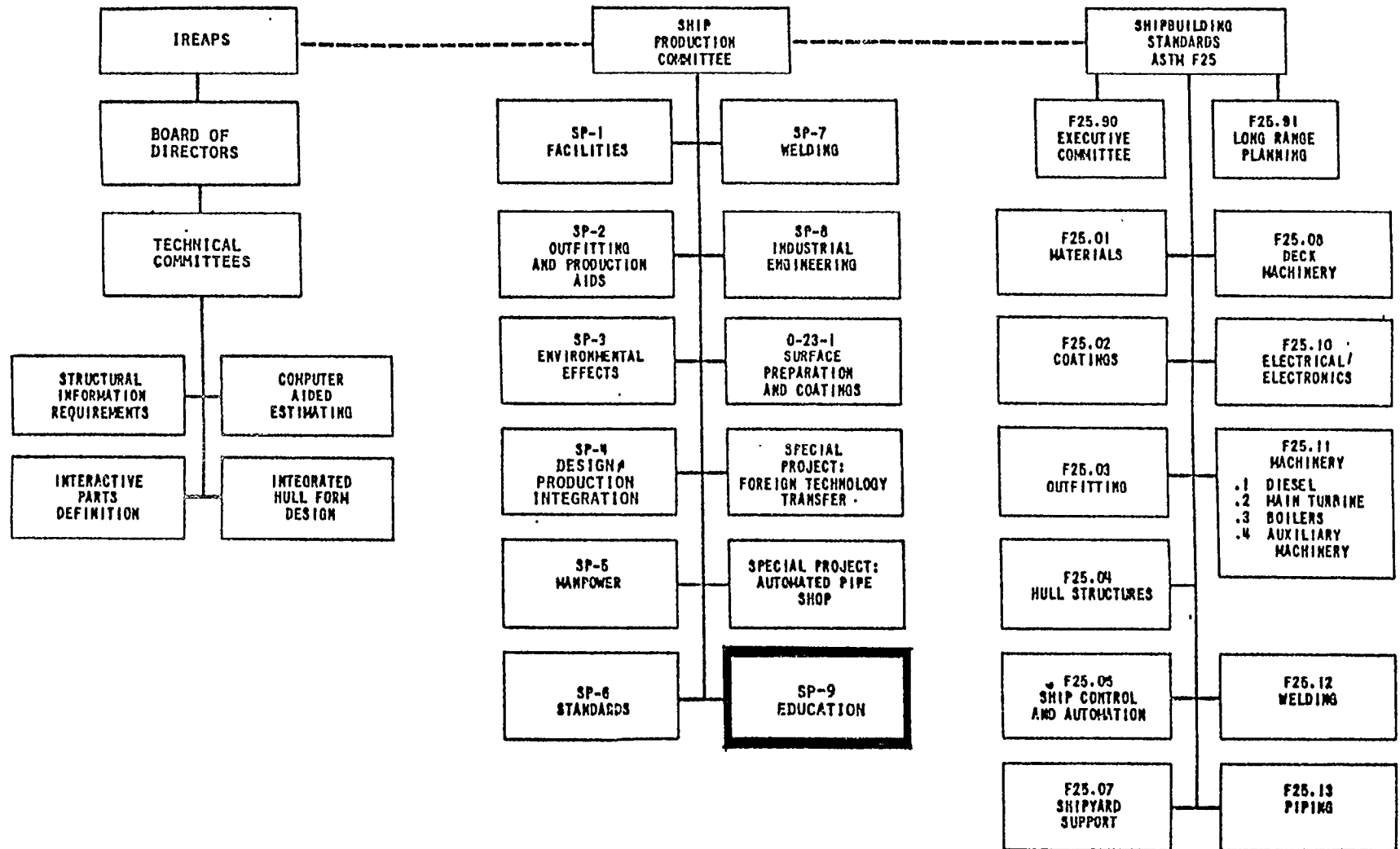
## SP-9 - EDUCATION

Howard M. Bunch  
Associate Professor  
Department of Naval Architecture and Marine Engineers  
University of Michigan

The Panel's purpose is to coordinate the development and emplacement of programs for education in the range of technical skills required to improve shipyard productivity. This includes technician training, middle management refresher training, and higher education initial-entry professional training.

The panel was established in May 1981, and has held a workshop to develop a program for the 1982 fiscal year. The projects proposed activities are in the three areas mentioned in the preceding paragraph.

# **NATIONAL SHIPBUILDING RESEARCH PROGRAM INDUSTRY ORGANIZATION**



SHIP PRODUCTION COMMITTEE  
EDUCATION PANEL

HISTORY

\* \* \*

ESTABLISHED IN APRIL, 1981

\* \* \*

PURPOSE IS TO DEVELOP AND MAINTAIN EDUCATIONAL  
PROGRAMS RELATING TO THE LATEST TECHNOLOGY IN  
SHIP PRODUCTION AND PLANNING, SPECIFIC AREAS  
OF CONCERN ARE:

- SKILLED TRADES TRAINING
- PRE-ENTRY PROFESSIONAL TRAINING
- MIDDLE MANAGEMENT REFRESHER TRAINING



\*\*\*    \*\*\*    \*\*\*

## FIRST PANEL WORKSHOP HELD IN AUGUST, 1981

\*\*\*    \*\*\*    \*\*\*

### 20 ATTENDEES FROM

- 7 PRIVATE SHIPYARDS (AVONDALE, BATH, BETHLEHEM LOCKHEED, NEWPORT NEWS NORSHIP, TODD)
- 1 NAW SHIPYARD (NORFOLK)
- 3 GOVERNMENT OFFICES (MARAD NAVMAT, NAVSEA)
- 3 UNINERSITIES (MICHIGAN, SUNY, WEBB)
- . 1 NON-PROFIT INSTITUTE (IRAPS)

\*\*\*    \*\*\*    \*\*\*

45 PROGRAMS CONSIDERED

8 ACCEPED

\$300<sup>K</sup> BUDGET

EDUCATION PANEL  
PROPOSED BUDGET LOCATION FY 82

	<u>(\$000&gt;</u>
SKILLED TRADES TRAINING	45
PRE-ENTRY PROFESSIONAL TRAINING	90
MIDDLE MANAGEMENT REFRESHER TRAINING	100
ADMINISTRION	65
	<hr/>
TOTAL BUDGET	300
	<hr/>

EDUCATION PANEL  
SKILLED TRADES TRAINING

- COMMUNICATE NAVSEA PROGRAMS  
PRIVATE SHIPYARDS \$20<sup>k</sup>  
 (INFORM PRIVATE U.S. SHIPYARDS OF  
 THE EXISTANCE OF ME NAVSEA TRAINING  
 PROGRAMS; SURVEY PRIVATE YARDS FOR  
 THEIR TRINING NEEDS, AND FORWARD TO  
 NAVSEA FOR USE IN THEIR PROGRAM  
 PLANNING)
  
- CATALOGUE OF TRAINING PROGRAMS \$25<sup>k</sup>  
 (COMPILE A DIRECTORY OF TRW-SKILLS  
 TRAINING ACTIVITIES AND MIDDLE-MANAGEMENT  
 TRAINING ACTIVITIES USED IN U.S. SHIPYARDS) \$45<sup>k</sup>

EDUCATION PANEL  
PRE-ENTRY PROFESSIONAL TRAINING

- CURRICULUM DEVELOPMENT \$30<sup>k</sup>  
ANALYZE AND IDENTIFY CLUSTERS OF SKILLS AND KNOWLEDGE REQUIRED FOR ENTRY INTO SHIP PRODUCTION, DEFINE THE MORPHOLOGY OF SHIPBUILDING TECHNOLOGY. PROVIDE SUPPORT FOR FACULTY ASSIGNMENT PROVIDE SUPPORT FOR ESTABLISHING PROFESSIONAL AWARDS ON SHIP PRODUCTION)

- SHIP CONSTRUCTION TEXT AND CASE STUDIES MANUAL \$45<sup>k</sup>  
(PREPARE UNIVERSITY-LEVEL TEXT BOOK ON SHIPBUILDING PROCESSES, DEVELOP CASE STUDIES TO ILLUSTRATE TECHNOLOGY OF PRODUCTIVITY).

- CLASSROOM MODELS \$15<sup>k</sup>  
(DETERMINE WHAT TYPES OF MODELS ARE APPROPRIATE FOR CLASSROOM USE, DEVELOP PLAN FOR PLACING MODELS INTO CLASSROOM).

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\$90<sup>k</sup>

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EDUCATION PANEL  
MIDDLE-MANAGEMENT REFRESHER

- ADVANCED TECHNOLOGY SHORT COURSE \$ 35<sup>K</sup>  
CONDUCT Two SHORT COURSES ON  
CONCEPTS OF ADVANCED TECHNOLOGY IN  
SHIP PRODUCTION, PREPARE VIDEO TAPE  
OF COURSE AND EDIT FOR USE IN SHIPYARDS>.
- QUALITY CIRCLES \$ 45<sup>K</sup>  
(PREPARE AND PRESENT TO SHIPYARD  
MANAGEMENT A PRESENTATION ON  
QC SYSTEMS, PRESENT TWO ONE-WEEK  
TRAINING PROGRAMS FOR FACILITATORS,  
PREPARE VIDEO TAPES FOR REFRESHER  
USE).
- TECHNIQUES OF SURFACE PREPARATION  
AND COATING \$ 20<sup>K</sup>  
(REPEAT FOR AN EXPANDED AUDIENCE  
THE TRAINING PROGRAM DEVELOPED IN  
1979 BY PANEL 0-23-1),

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\$100<sup>K</sup>

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THE AUTOFIT CAD/CAM SYSTEM FOR PIPING ENGINEERING:  
OPERATIONAL EXPERIENCE AND DEVELOPMENT STATUS

Frank Dahle  
Shipping Research Services A/S  
Oslo, Norway

ABSTRACT

AUTOFIT is built up around a main database that includes all information necessary for piping design and detail engineering. The system is also prepared to interface other tasks and functions as: analyses, planning, shop automation and including other engineering disciplines (steel structuring, material control, purchasing, quality control).

AUTOFIT meets the modern needs for communication through a flexible command processor. Here the user can choose his own user interface such as language, screen configuration, several ways of giving input, or degree of interaction.

## 1. INTRODUCTION

AUTOFIT is an abbreviation for OUTomatted outFITting and the name of a computerbased technical information system for piping engineering.

The system is partly in use and under development and will finally cover the total piping engineering discipline, from system schematics (P&I-diagrams), via Layout(Arrangements) to generation of production information (Isometric drawings e.t.c.) .

## 2. THE PEOPLE e. ENGINE) THE SYSTEM

The idea of AUTOFIT was created in machinery departments in the 'AKER GROUP OF SHIPBUILDERS AND OFFSHORE CONTRACTORS' in the middle of the 1970's.

Since the Aker Group already was involved in successful system development through a joint-venture between several research institutions in Norway(SIAG) , nothing was more natural than starting the development of this new system for piping engineering.

## 3. THE AUTOFIT CONCEPT

AUTOFIT is established on a product module for the total piping engineering discipline and built around a main database that includes all informations necessary for piping design and detail engineering.

The system is also prepared to interface other tasks and functions as: analyses, planning, shop automation and not to forget other engineering disciplines(steel structuring, material control, purchasing, quality control).

It is very important to mention that AUTOFIT is made to gain not only the ship problem, but also the more complex nature of petrochemical and chemical plants whether onshore and offshore.

AUTOFIT meets the modern needs for communication through a flexible command processor. Here the User can choose his own user interface such as language, screenconfiguration, several ways of giving input, degree of interaction e.t.c.

## 4. THE AUTOFIT SUB SYSTEMS

Figure 1 shows the major tasks involved in the total process of piping design and production engineering, including material take-off.

Done in the conventional way, these tasks may be divided into three rather logical phases:

- functional design resulting in a P&I diagram with all associated information in the form of drawings, lists, E. t. c.
- lay-out design using either orthogonal arrangement drawings or building a small scale physical model, both visualizing the final arrangement

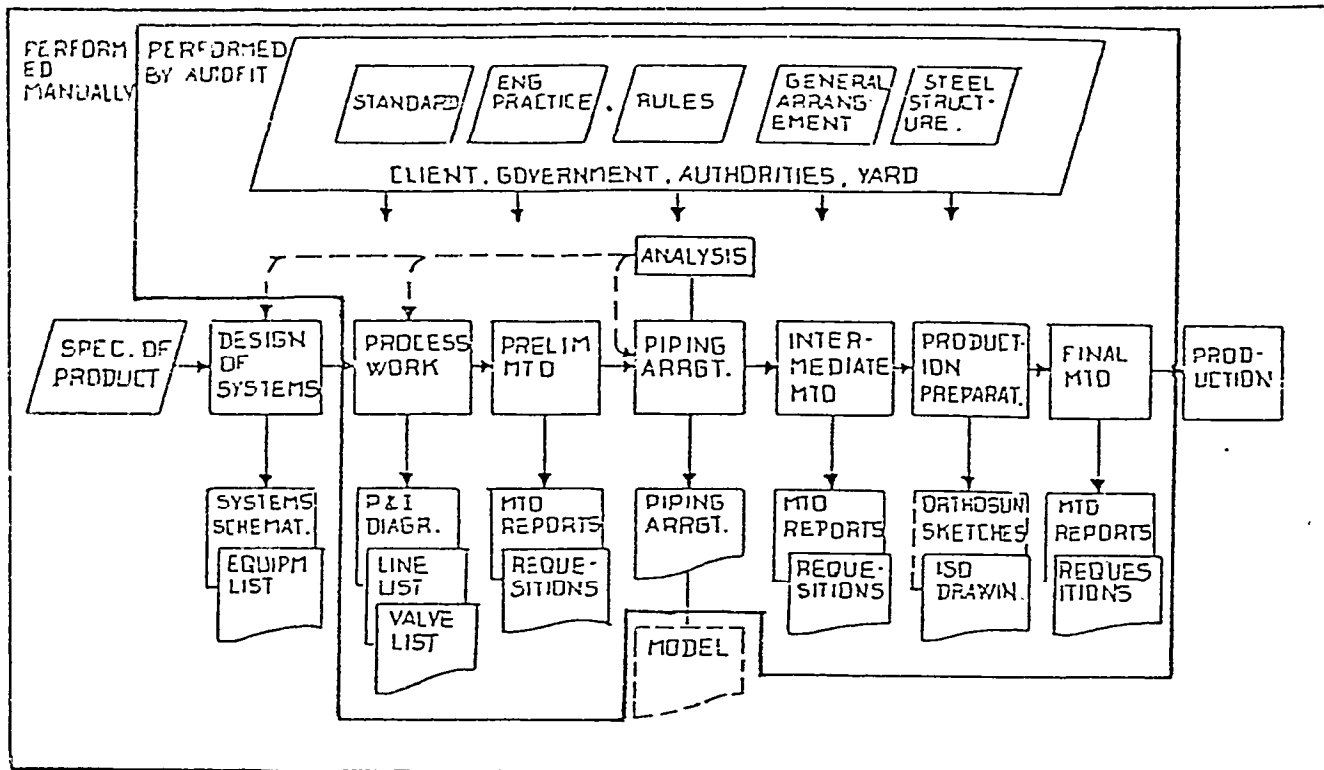


Fig. 1. Process diagram for the total engineering

- Both phases involves a variety of calculations and analyses.
- preparation of work shop documentation such as isometrics, piece drawings, material lists, e. t. c.

In parallel with these tasks, the designer has to do material take off.

The figure indicates the tasks of conventional process which are included in the computerization. It appears that design of flow diagrams or system schematics are assumed to be done manually.

Figure 2 shows a general view of AUTOFIT, divided into main functions or sub-systems, which correspond very closely to the sub-division of work just described.

- DIAGRAM - contains all functions up to complete P&I diagrams with associated information. The subsystem will also build a topological flow-structure in the database.
- LAYOUT - contains functions for arranging equipments and pipelines. The sub-system will store geometry data in the database and generate arrangement drawings and views.

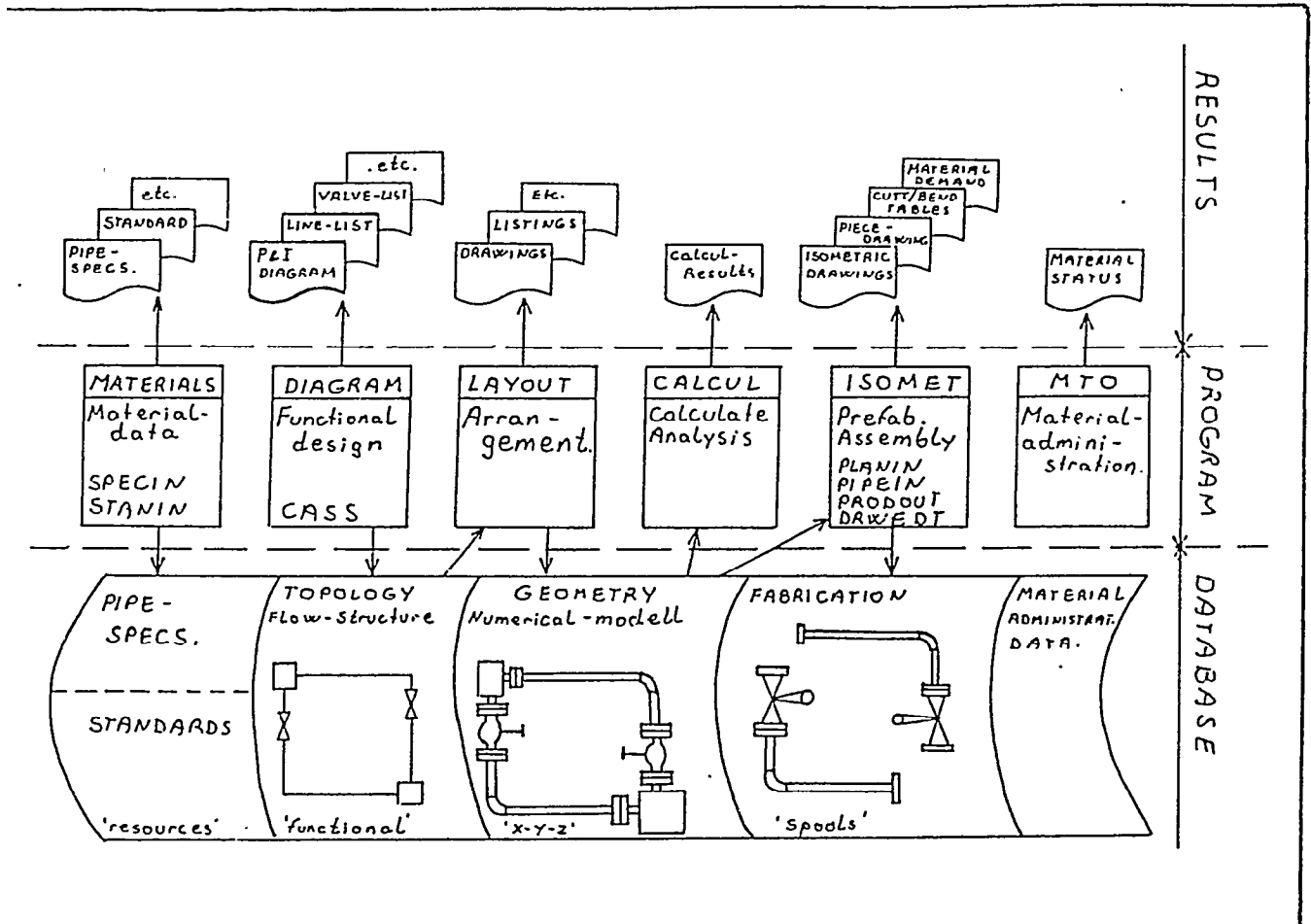


Fig. 2. AUTOFIT-sub-systems

- ISOMET - contains functions for specifying production information and generating production documents such as isometric drawings, material lists e.t.c.
- CALCUL - interface between the product model and various calculation programs.
- MTO - material administrator.
- MATERIALS- functions for handling of standards and pipe-specifications. I.e. preloading of important data to be utilized by the other sub-systems.



the subsystems are supposed to be integrated (with each other), i.e. one sub-system generate data to be used by the next. However, it is fully possible to use the subsystems individually as stand alone systems. ISOMET may then be used without going through the two previous phases, DIAGRAM and LAYOUT.

#### 4.1 . DIAGRAM

DIAGRAM is the name of *the* subsystem in AUTOFIT dealing with the making of P&I diagrams(schematics). The final version of this subsystem will, in addition to the drawing of diagrams, also build the nucleus of numerical product model in the database for further use in the subsystems LAYOUT and ISOMET. DIAGRAM has been divided into these. modules.

- CASS - generate p&I diagram drawings
- GENBAS - based on the graphical representation made by CASS, this module will build the nucleus of product. model in the database.
- EQUIPIN- description of equipment in the database.
- TRANSP - tool for calculating transport demand in the pipesystems. This is essential data for the dimensioning of pipes and armature.
- CADCON - calculation of pipe-dimensions and selection of standard pipes and fittings according to the pipe-specifications.
- CADARM - selection of armatur according to pipe-specification.
- INSTRM - definition of instrumentation to the database,

These modules are implemented as sets of commands under the command processor and thus occur as one executable program.

#### 4.2. LAYOUT

This is the module of the AUTOFIT concept that handels the piping layout problemes. From the DIAGRAM module we get the piping design topology, that in LAYOUT can be expanded with space geometry.

In this new module we have not only converted the old drafting means as drawingboard and pencils, but also integrated completely new tools based on functional drafting design.

Through the introduction of computers we namely have got new design possibilities that will not be efficiently used by just copying traditional layout procedures and methods.

The main objects for LAYOUT is to GENERATE THE GEOMETRY of piping systems so that they can become as FUNCTIONAL AS POSSIBLE, EASY TO BUILD with a MINIMUM OF MATERIAL COSTS and a MINIMUM OF DESIGN HOURS AND TIME.

Starting with these global objects, the design process was structured, more specific objects were formed, and boundaries were taken into consideration. The mapping process from the objects to the new concept will not be discussed here. I will just mention some of the objects and boundaries:

- The layout module shall be able to use the information generated by DIAGRAM.
- The LAYOUT module shall be able to generate all the geometry for a piping system.
- The LAYOUT module shall generate necessary information for ISOMET.
- The LAYOUT module can be used independently of the other AUTOFIT modules.
- LAYOUT shall handle a dynamic information process from estimated to exact information.
- It must be possible to use the system independently of the time when the different information is available.
- The design process must be structured into tasks, in which the designer, with help of the system, has the fully view.
- The easiest way of producing a piping system shall be the easiest way of designing it.
- The easiest way of designing a piping system shall ensure low material costs.
- Functional, operative and safety requires must easily be taken care of in the layout process.
- Many designers shall be able to work with the same project.
- All decisions shall be taken by the designer, or if he/she decides, by the system.
- The input information shall be a minimum.
- The input information shall be given to the system with a minimum of time.
- The input information shall be given into the system in the same form as it is available for the designer.
- The structuring of the design process shall ensure an optimum solution, and each task shall be optimized within the boundaries of the structure.
- Every stage in the design process shall be faster using LAYOUT than a 3-D model or a drawingboard. -np; If wanted, it shall be possible to take out parts of a project and handle them manually.
- It must be possible to change all kinds of information.
- Change of information shall influence on a minimum of the designed system.

- It must be possible to create alternative solutions in all steps in the layout process with a minimum of efforts.
- The designed piping system shall be without interference between pipes, instrumentation and surroundings.
- The LAYOUT-module shall produce the following output:
  - i) geometric information to ISOMET. block model drawings.
  - ii) other information for building block model.
  - iii) arrangement drawings in projections or isometrics with desired degree of detailing.
  - iv) information for building 3-D detailed model
  - v) information to the material take-off system at every topical stage with estimated or exact data.
- LAYOUT shall use the same hardware configuration as the other AUTOFIT modules.
- The first version of the LAYOUT module shall be ready within a year.

The new LAYOUT concept is already satisfying most of these objects, and by further detailing with assistance from a group of designers we hope to satisfy the rest within a year. The concept has ensured that the need of computer programs is realistic. Having worked with functions long enough in the design process, we realised that most of these could be covered by using existing programs in a new way and in new combinations.

The main sub-modules of the LAYOUT module are:

#### 4.2.1. STRUCTURING MODULE

TAKING THE COMPONENTS, PIPELINE TOPOLOGY AND DIMENSIONS from DIAGRAM, the designer is able to create alternatives for the structuring and choosing the best from analyses for each of them. This module is already on the market.

#### 4.2.2. GENERATING OF SURROUNDINGS

The surroundings of the piping structure must be brought into the database in an efficient way. The new drafting modules in the AUTOCON-system, AUTOPART/AUTODRAW, will care for most of these functions.

#### 4.2.3. GENERATING OF COMPONENTS

This module consists of methods for transferring manufacturers data into a 3-D database. Digitizing tecnics and a 3-D grafic component generator will here be used

#### 4.2.4. LAYOUT AND ROUTING

Almost the same programs that are mentioned before will be used in this matter.

#### 4.2.5. INTERFERENCE CONTROL

All kinds of mathematical and visible control has to be available.

#### 4.3. ISOMET

ISOMET is the name of the subsystem in AUTOFIT dealing with the generation of production information, such as:

- Isometric drawings.
- i) Material summaries.
- ii) Cutting and bending information.
- iii) Pipe sketches.

In the total AUTOFIT concept this sub-system will use the information stored in the product model by the previous subsystems DIAGRAM and LAYOUT. However, ISOMET may also be operated as a stand-alone-system. The description of pipe-lines will then have to be lifted from drawings or a physical model and fed into the database. A first version om has existed for some years and been used in some projects for generating of isometric drawings. This version is basically batch oriented and runs on a UNIVAC computer. The next version will be ready for piloting during this summer. It will be interactive and running on a local computer. The following will be a description of this new version. The sub-system will consist of five modules: SYMIN, PLANIN, PIPEIN, PRODOUT and DRWEDT(fig.)

- SYMIN is a program for defining drawing symbols in the database. The symbols may be rotated and sheared in order to be used directly in the making of isometric drawings.
- PLANIN is a program for definition of reference planes, lines and points. These data are used in the PIPEIN program for positioning items relative in space.
- PIPEIN is the program for defining pipelines if ISOMET is operated as a stand-alone-system or for adding production information to the pipelines defined in LAYOUT. The program will build datastructures which is able to hold complex pipe-structures. The commands available for manipulating pipelines may be grouped as follows:
  - i) Administration of SYSTEM, LINE and SPOOL.
  - ii) Selecting items according to pipe-specifications and standards.
  - iii) Positioning of items geometrically.
  - iv) Manipulating default values.
  - v) Adding special data to items.

- vi) Positioning along pipeline to make updatings.
  - vii) Controlling the screen picture if in graphical mode.
  - viii) Establishing relative references(in branches, etc.)
  - ix) Establishing production units(spools).
  - x) Displaying various informations from the database.
  - xi) General commands for preceding in manuscripts. etc.
- The data stored by PIPEIN will contain position of all items, length of all pipes and bending angels of all items requirering change in directions.
  - PRODOUT is the program for extracting data from the datastructure made by PIPEIN and produce various production information. The program will have commands for (fig. ss):
    - i) Administering drawings: define, delete, etc.
    - ii) Administering drawing contents: adding/removing information in drawings.
    - iii) Generating of production information according to defined drawings: isometric drawing, material lists, etc.
    - iv) Certain abilities to influence on the graphical picture: measurments, shading, texts, etc.
  - The definition of the drawing(drawing content) will be stored on separate files and will later be modified and used to generate new output.
  - The grafical and tabulary output may be stored on files for later manipulation by the program DRWEDT.
  - DRWEDT is a general program for editing of drawings. In ISOMET it will perform the following tasks.
    - 1) Make "cosmetic" changes to the pictures made by PRODOUT in order to make the drawing clearer.
    - ii) Merge the graphical part of the drawing with the material list and drawing frame in order to make a complete drawing.
  - The program is totally interactive and is operated via a graphical screen.
  - The final result may look like the drawing shown on fig. ss.
  - MATERIALS. Pipelines consists , to a large extent, of prefabricated items;, such as elbows: tees, valves, reducers, gaskets, etc. Each of these different item types have their own properties and for each type a variety of sizes exists. To store and maintain information about all these articals the program STANIN has been made. Data is stored in standard headings and dimension tables.

- The heading contains general information about a standard and the dimension tables contains the geometric data about the various sizes within a standard. Due to the different properties of the item types, nine types of dimension tables has been defined. One dimension table may be shared between several standard headings and thus saving work in definition and saving space in the database.
- In order to control the selection of standards for a particular pipe-system in a project, a pipe-specification program is made. The use piping specifications is commonly used in the oil/offshore industry, but not commonly used in shipbuilding. From the specification the engineerer will decide which standard to be used when selecting material. To store and maintain pipe-specifications in AUTOFIT the program SPECIN has been developed.
- The main reason for these two programs (STANIN and SPECIN) is to automate the selection of material in the subsystem DIAGRAM. LAYOUT and ISOMET. However the programs may stand alone and thus be useful in systemating material data, providing material cataloges(STANIN), piping-specification-drawings and documents(SPECIN).

## 5. DEVELOPMENT STATUS

In addition to what is mention allready I will give a short summary of the developing status for each of the AUTOFIT subsystems:

- DIAGRAM exist in its first version and is planned to be completely finished in the beginning of 1982.
- LAYOUT is under development. Piloting of the first version will start within a year.
- ISOMET exists in its first version and is running into production for several yardnumbers in the Aker Group. A new version is ready for piloting.
- CALCULE which is the name of the interface between the database and certan calculating programs(f.ex. stress analyses, has to be adapted to the type of calculation program you are linking up to.
- MTO that takes care of material control matters is runned by the material 'administration program MAPLIS, that is another SIAG development. MAPLIS is today in full I production in all yards in the Aker Goup.
- MATERIALS (STANDARDS AND SPESIFICATIONS) are ready and in production.

6. OPERATIONAL EXPERIENCE  
AND - USER'S NEED

Submodules of the AUTOFIT concept have been taken into production as stand-alone versions on several yardnumbers in the AKER GROUP

I myself started out piloting the ISOMET module in 1977. The year after this system was used in regular production, first on the machinery room of a boat for the Norwegian Navies Coast Guard and later on a Production Compression Platform for the Valhall field in the North Sea. I mention these two projects because I know them very well being in charge of them as project leader.

Even though the piping problem for a ship and a offshore plant should be very much the same, we all know from experience that they are very different when it comes to administration, and this then influence the engineering procedures.

Let me just mention some subjects that may indicate this:

- i) different needs and rules for project control
- ii) different need of specifications
- iii) different need of documenting the work
- iv) different procedures for approving design and production documents.
- v) different ways to enforce design decisions

When implementing a computer tool in solving the piping problem we must choose or develop a system that handles all these different needs and ways, and that is able to be adjusted and expanded with very little effort.

The main case I would like to mention when judging a new piping design system, is the systems possibilities to handle the increasing range of new revisions and changes in the piping structure.

We hope that the new version of the ISOMET module of the AUTOFIT concept is going to handle this very well, especially because it is developed just to take care of this problem.

AUTODRAW: AUTOKON'S INTERACTIVE GRAPHICS SYSTEM FOR VIEWING  
AND MANIPULATING STRUCTURAL MODEL DATA  
INTO COMPLETE DRAWING DOCUMENTATION

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Oslo, Norway

1) THE PLACE OF AUTODRAW IN THE AUTOKON SYSTEM

Today AUTOKON is an integrated system for the ship-building industry. The system consists of a "BATCH" and an "INTERACTIVE" part. (See fig. 1.)

The batch oriented programs are:  
BOF/LANSKI/SHELL/TRALOS/TRADET/DRA17/PARTO/ALKON.

The interactive oriented programs are:  
DFREC/AUTO-NEST/AUTO-LINK/AUTO-INIT/AUTO-PART/  
AUTO-DRAW/KINGDRAW/TRAPAR

AUTODRAW is a program to verify the contents of a DATA-BASE and to make complete drawings with that data. Therefore we will not compare the system with line-drawing systems.  
The only "lines" drawn by AUTODRAW through input to the system are lines necessary to make the drawing complete, such as lines for dimensioning.



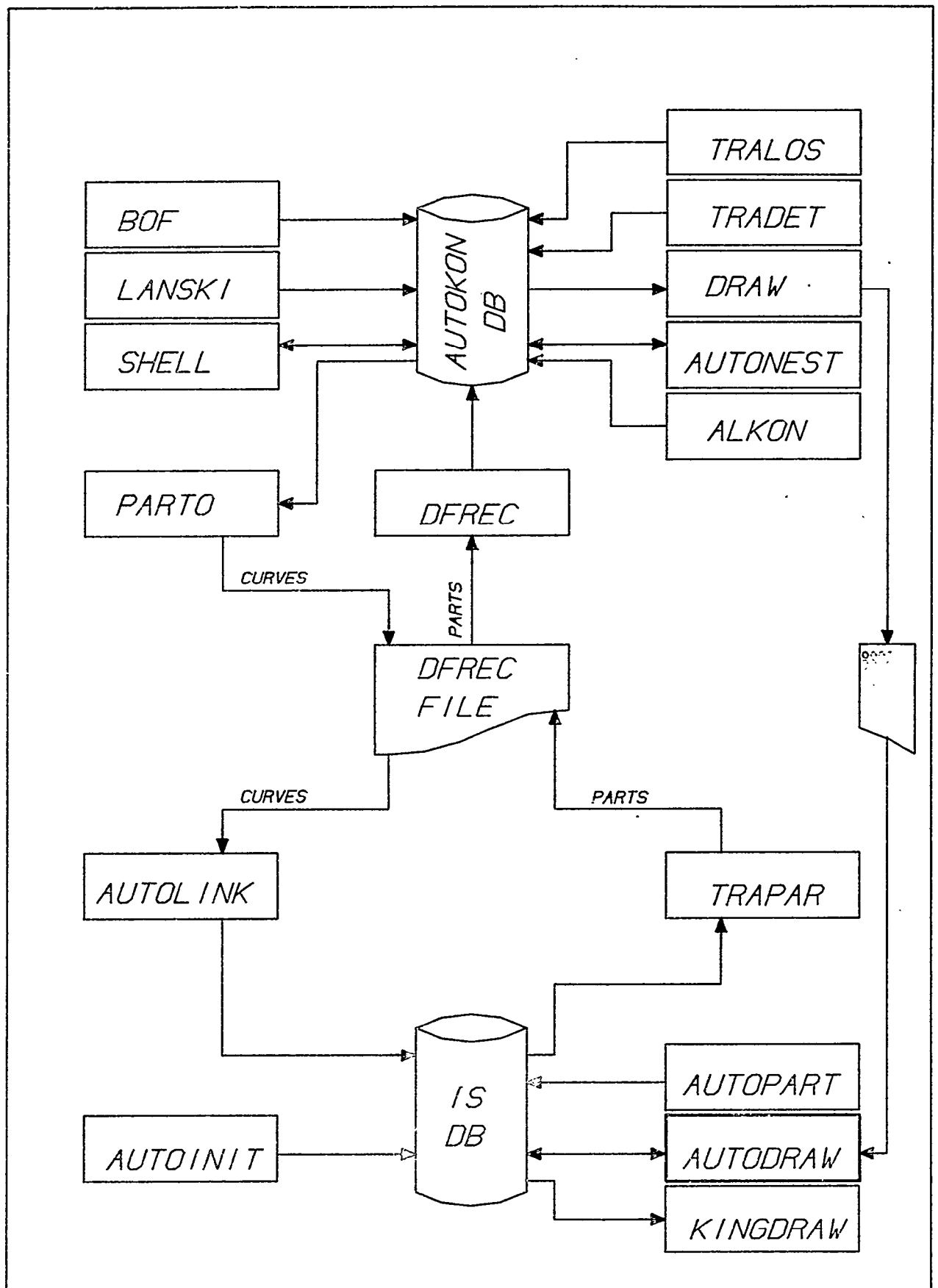


Figure 1

Today AUTODRAW can make complete drawings such as shown in fig. 2, 3, 4, 5, 6. The information for all parts is kept in the IS database and is generated by AUTOPART.

All the parts are positioned in relation to a common XYZ axis and therefore it is easy to make composite drawings. Position one part and the other will fall automatic in place.

From the batch side of the system one can read "papertape" files into AUTODRAW as being the basic drawing. AUTODRAW can now supply this picture with text, dimensions etc.

## 2) WHAT CAN BE DONE WITH AUTODRAW ?

The most important functions in AUTODRAW are:

### Verification

of contours, parts, assemblies and papertape files.

### Generation of drawings

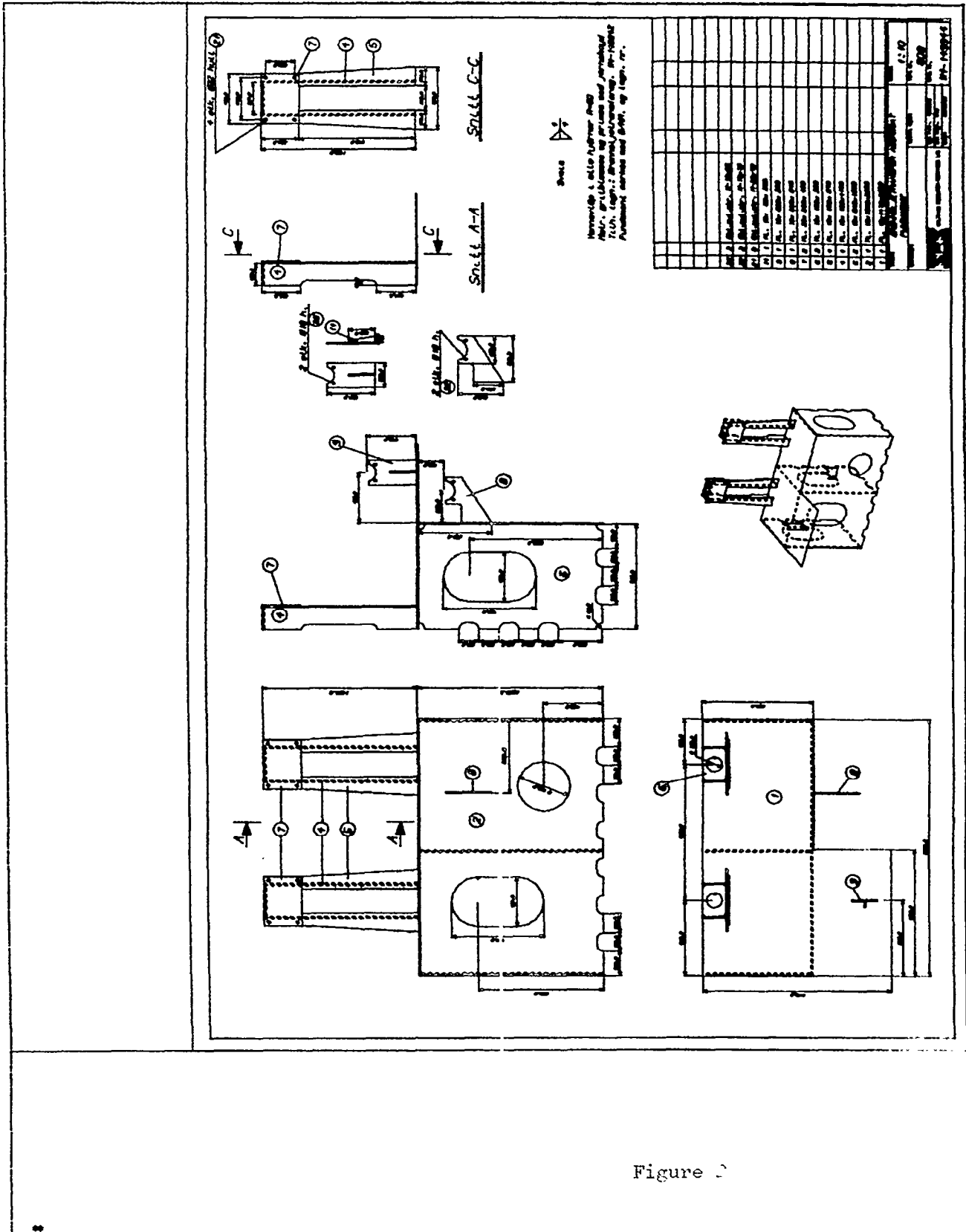
composition  
completion by:  
text  
symbols  
dimensions  
identification

General views:  
orthogonal  
perspective  
axonometric

An additional, but minor, function is that AUTODRAW may be used in the same way as a simple graphic turn-key system, as a drafting tool to make simple pictures on the screen.

The interaction between User and System is by commands following a certain syntax.

The commands are treated by a group of programs called the Command Processor common to most of the systems in the interactive program group. Commands are entered from keyboard menu or card-image files.



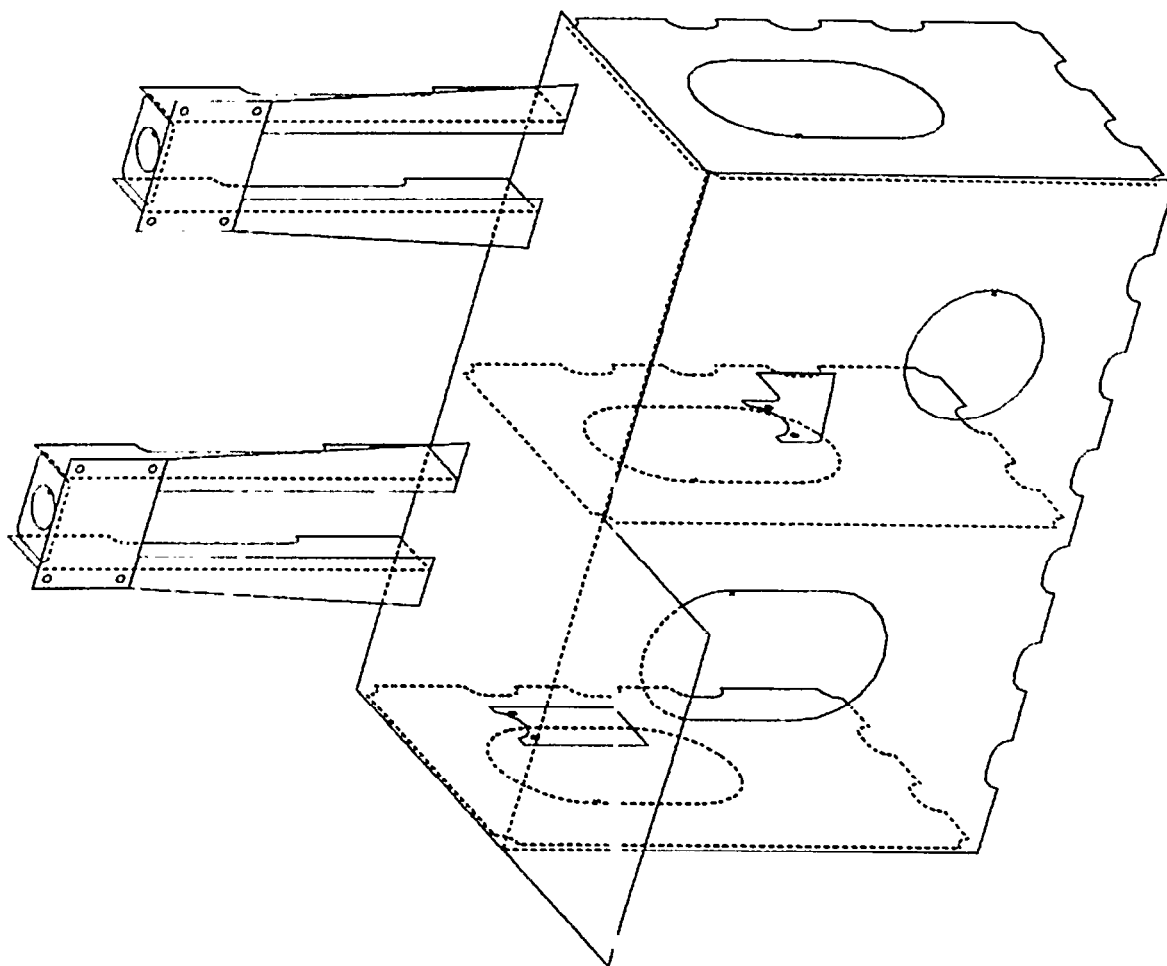
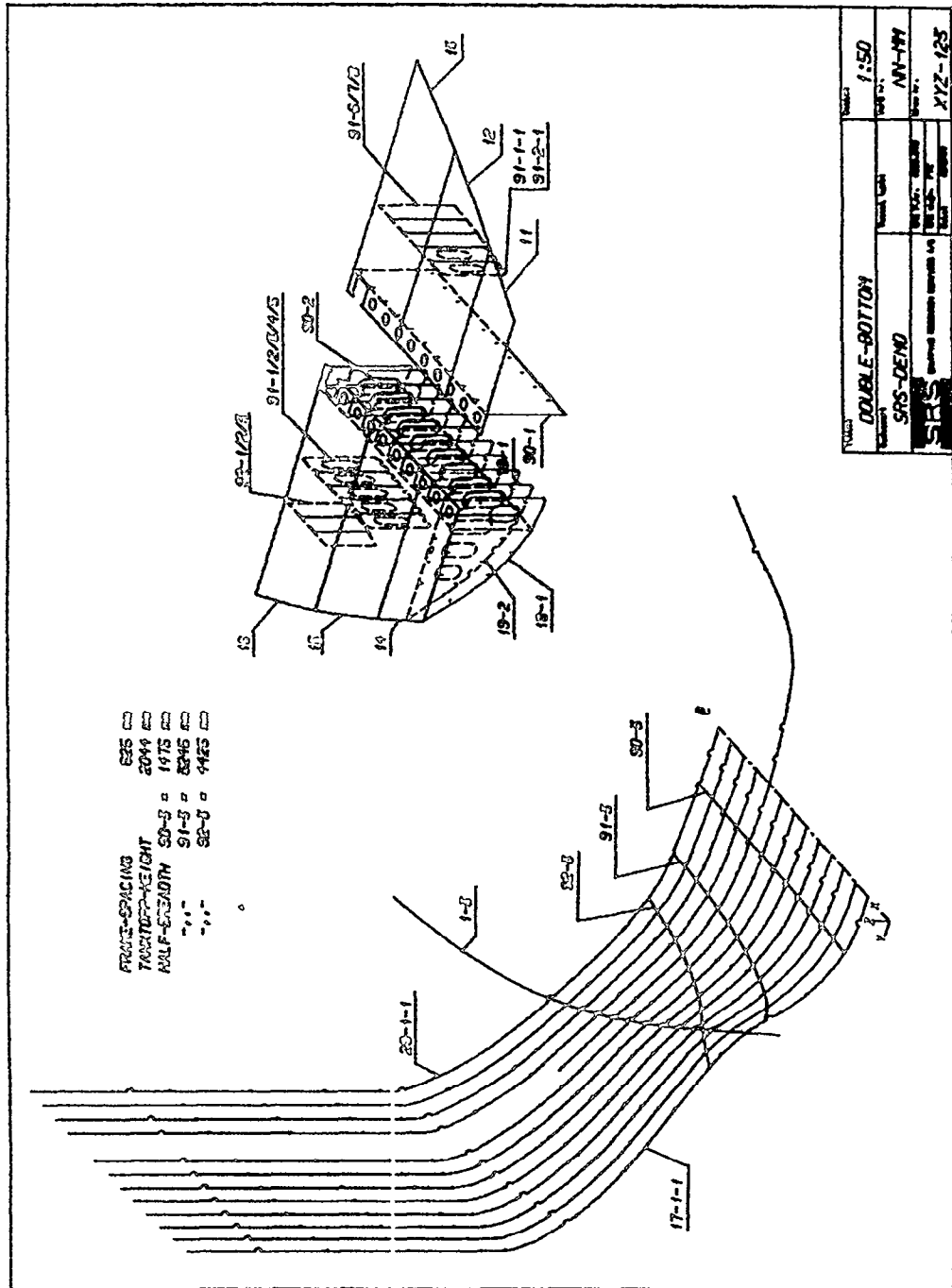
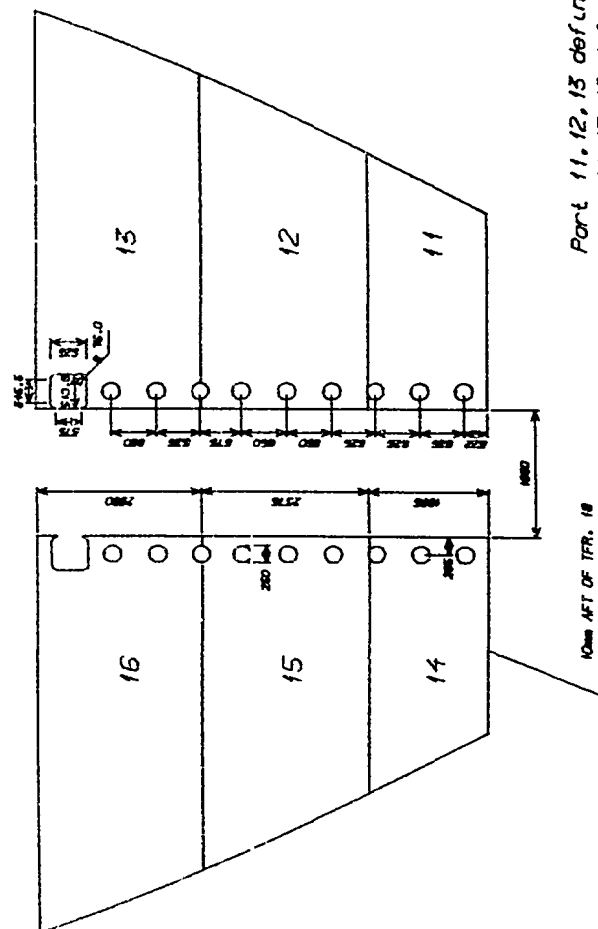


Figure 3





Tillett		Product	1:50
DOUBLE-BOTTOM		Part no.	NW-NM
Cumulant		Vessel type	
SRS-DEMO		Shd P.Nr.	9802.076
		Dredge nr.	

Figure 5

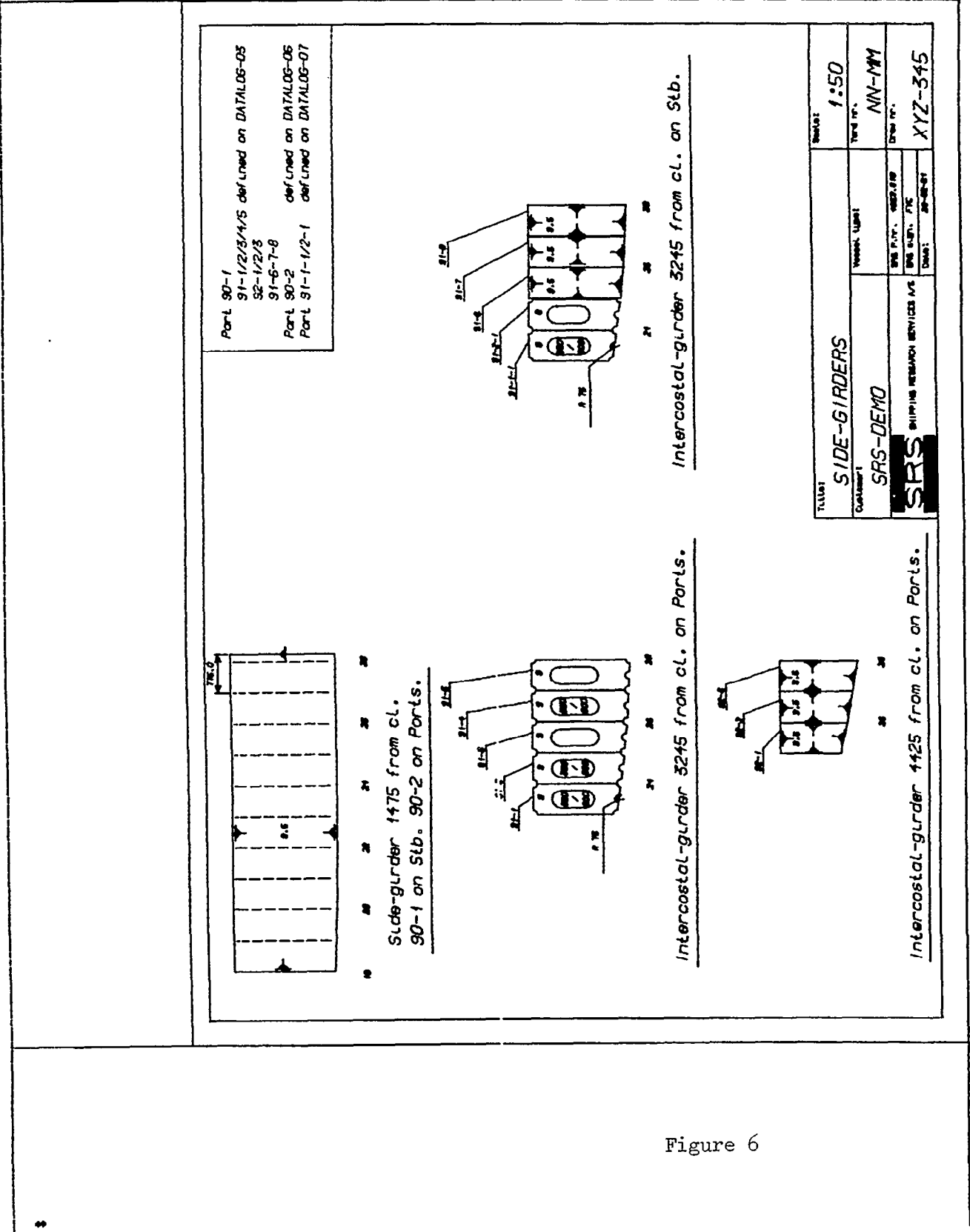


Figure 6

Arguments may follow the command, or be given as answers to dialogue questions.

E. g. If the user remembers the sequence of arguments he could define a new picture by writing:

```
BEGIN- PICTURE 109, YES, A1, YES
```

or, he could utilize the dialogue feature:

```
BEGIN- PICTURE
```

```
"PICTURE- NAME: " 09  
"STANDARD- A ?1: " YES  
"A- FORMAT : " A1  
"HORIZONTALLY?: " YES
```

(the questions asked by the system are between ").

The list of available commands are introduced to the system by the initializing program AUTOINIT. The names of the commands may be changed by the user, and several different names may be connected to the same command.

The available commands fall in two main groups:

The commands specially valid for AUTODRAW

The commands common to other interactive systems.

Logically a drawing is built as a hierarchy of three levels, called PICTURE, SEGMENT and OBJECTS (See fig. 7).

A PICTURE consists of one or several segments, a SEGMENT contains a number of OBJECTS of different types.

The OBJECT types are:

```
PART  
CURVE  
SYMBOL  
TEXT  
DI Mension
```

The concept of segment is introduced to separate a picture into logically distinct partitions. When a new picture is started a segment with number zero is automatically initiated and all objects belong to segment zero if no other segment is defined.



The commands by which the user manipulates his drawing operate on a full picture, a segment or one particular object.

A typical sequence for building a segment is shown in fig. 8, 9, 10, 11.

Another general feature is the use of MACRO's. Fig. 12 shows the result of two MACRO's, one written in AUTOPART to generate all the lines for a title field and the other written in AUTODRAW to complete the title field with the text.

A MACRO may be any combination of commands which will be executed by calling up the MACRO name.

### 3) HOW SHOULD AUTODRAW BE USED FROM EARLY DESIGN TO SHOP DRAWING

---

Fig. 13 shows how the system will look like at the end of this year. We will add some new link programs so that we can use more information generated with TRALOS and TRADET.

The system may then be used as follows:

The first step will be to do a preliminary fairing to create the design frames necessary to make the classification drawings by means of TRALOS/TRADET. DRAW will be used to generate a papertape file which will be read by AUTODRAW. AUTODRAW is now used to make the drawings complete with text and dimensions. After the classification phase curves generated by TRALOS/TRADET are transferred to the IS database with the link programs DRAW IS and AUTOLINK.

All production parts may now be coded with AUTOPART.

AUTODRAW is now used to make complete shop-drawings for assemblies, single parts etc.

PARTS will be nested by means of AUTONEST to produce papertape for production.

# PICTURE & SEGMENTS

A PICTURE MAY HAVE  
SEVERAL SEGMENTS.

IN THIS EXAMPLE IT  
IS CONVENIENT TO  
PARTITION THE PIC-  
TURE INTO 3 SEGMENTS

THE TITLE AREA

THE CURVES

THE ASSEMBLY

TO SHIFT BETWEEN  
SEGMENTS WE USE  
THE COMMANDS:

'BEGIN-SEGMENT'

'RESUME-SEGMENT'

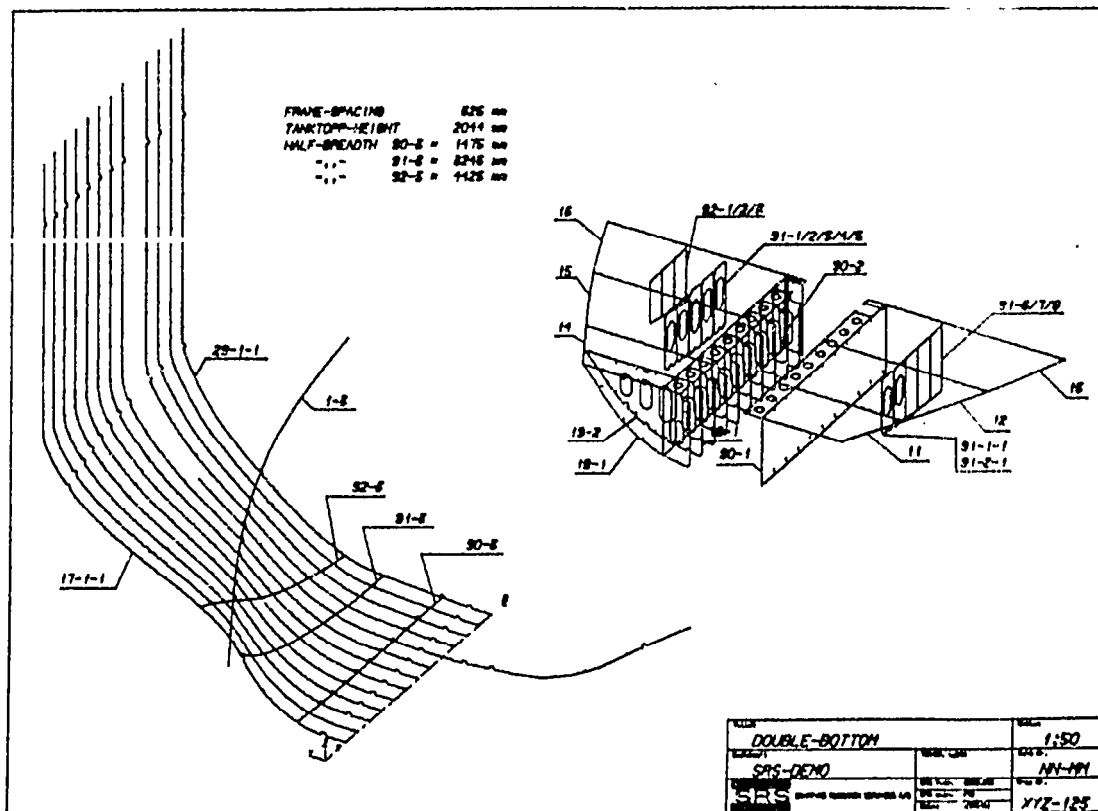


Figure 7

Figure 8

```
*BEGIN-PICT 13,Y,A2,Y  
*SHOW-AXIS-GLOBAL  
*SET-SCALE 0.05  
*
```

THIS PICTURE IS TO BE  
USED FOR 7 STRUCTURAL  
PARTS IN AN ASSEMBLY.

THE SCALE FACTOR IS  
CHOSEN TO TRANSFORM  
BETWEEN 'REAL' VALUES  
AND THE SIZE OF THE  
DRAWING PAPER. (NOT  
THE ACTUAL SIZE OF  
THE TEKTRONIX SCREEN!)

'SAME-PART'

1/4

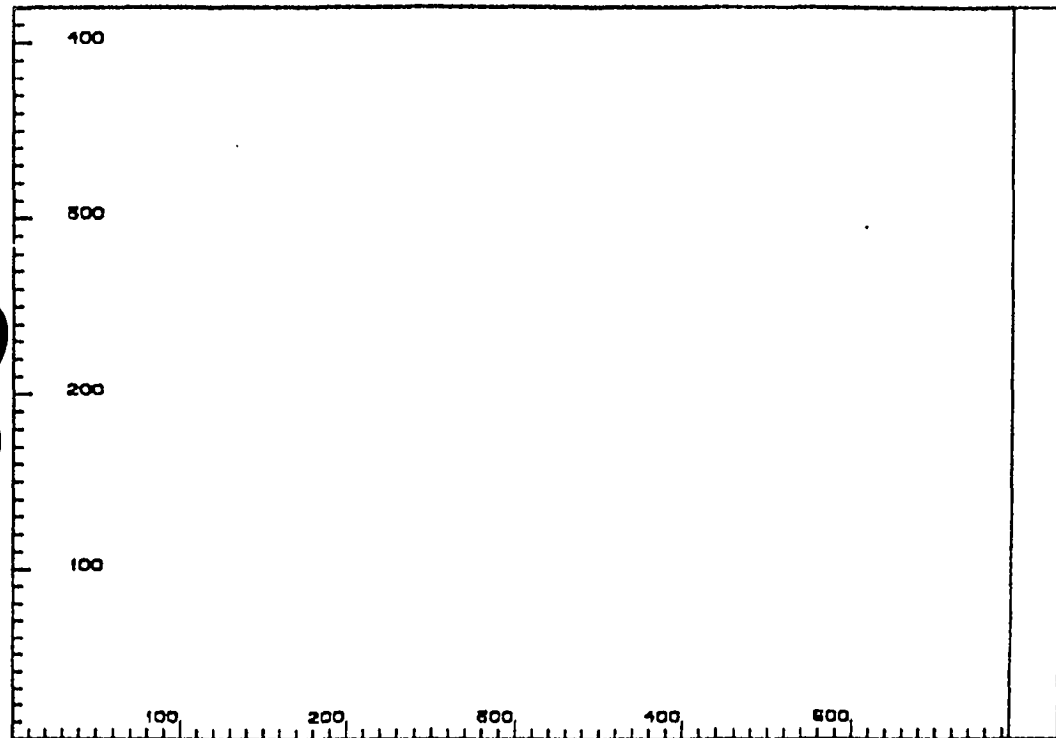


Figure 9

```
#FETCH-PART 90-2  
#POSITION x  
#ROTATE-X -90  
#ROTATE-Y 45  
#ROTATE-X 30  
z
```

THIS SERIES OF ROTATIONS  
HAS POSITIONED ONE OF  
THE PARTS THAT WE HOPE  
WILL GIVE A GOOD 3-D  
PICTURE OF THE ASSEMBLY

'SAME-PART'

2/4

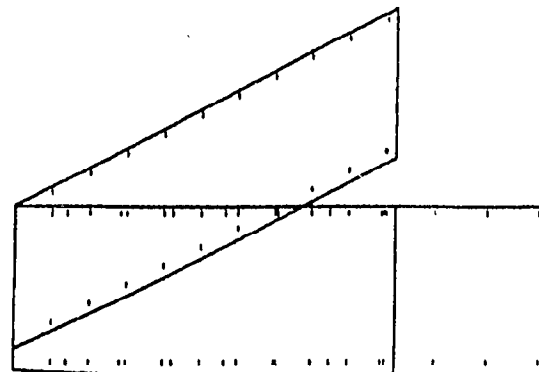
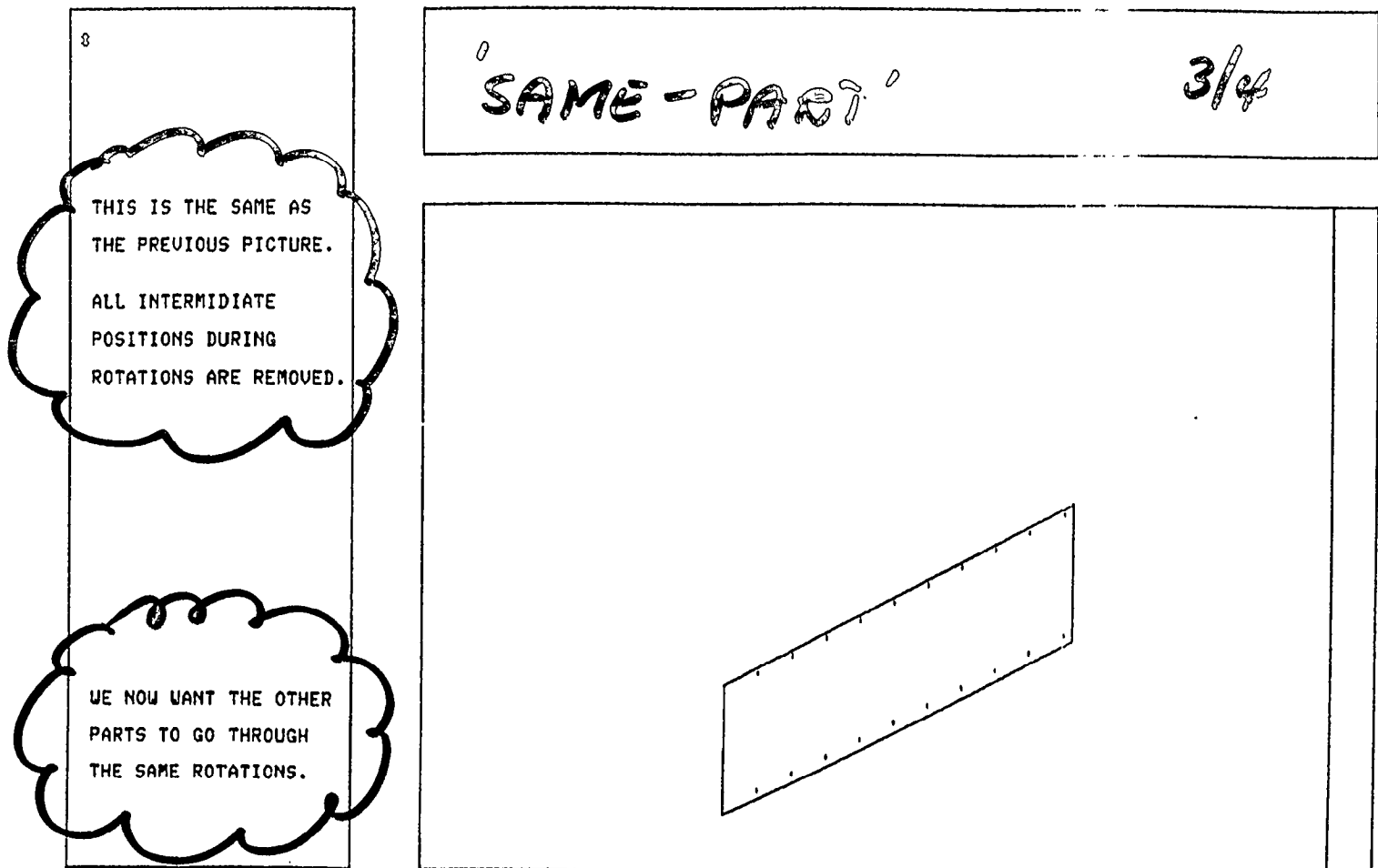


Figure 10



```
$SAME-PART 14  
$SAME-PART 15  
$SAME-PART 16  
$SAME-PART 18-1  
$SAME-PART 19-1  
$SAME-PART 19-2  
$
```

THE 'SAME-' COMMAND  
IS EQUIVALENT TO A  
COMBINATION LIKE:

- 1) FETCH-
- 2) POSITION
- 3) ROTATE
- 4) ROTATE

ETC ...

ALL OPERATIONS ON THE  
CURRENT OBJECT ARE  
REPEATED.

'SAME-PART'

4/4

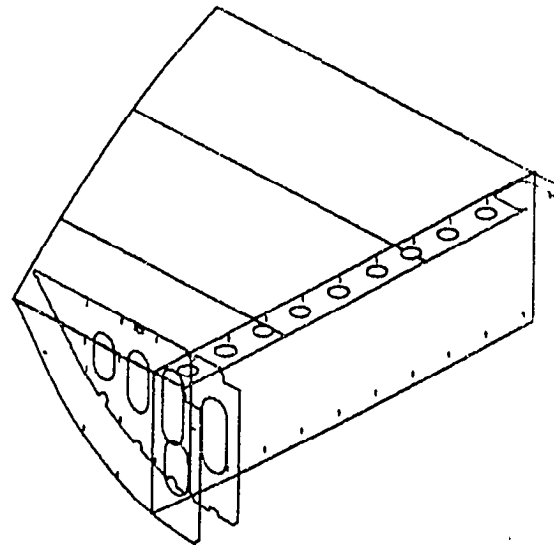


Figure 11

Macro

-----

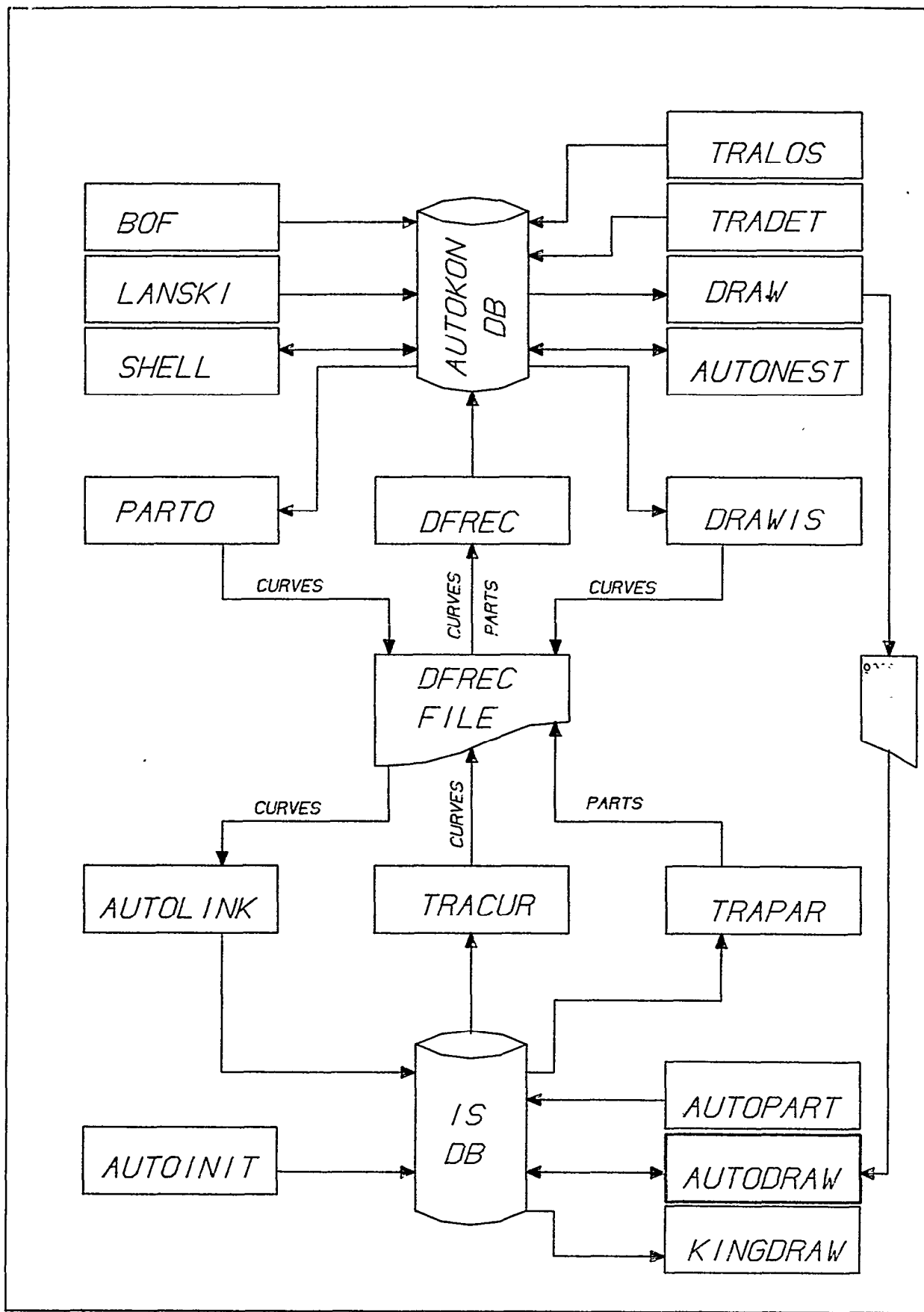
A complex example:

We want a macro to draw the title-field  
on a drawing.

Title: <i>DEMONSTRATION OF MACRO</i>		Scale: <i>1/1000</i>
Customer: <i>SOMEBODY</i>	Vessel type: <i>YACHT</i>	Yard nr. <i>123</i>
<b>SRS</b> SHIPPING RESEARCH SERVICES A/S	SRS P.nr. <i>12545</i>	Draw nr. <i>123-0</i>
	SRS sign. <i>FVC</i>	
	Date: <i>JUNE/81</i>	

The frame in AUTOPART


Figure 12



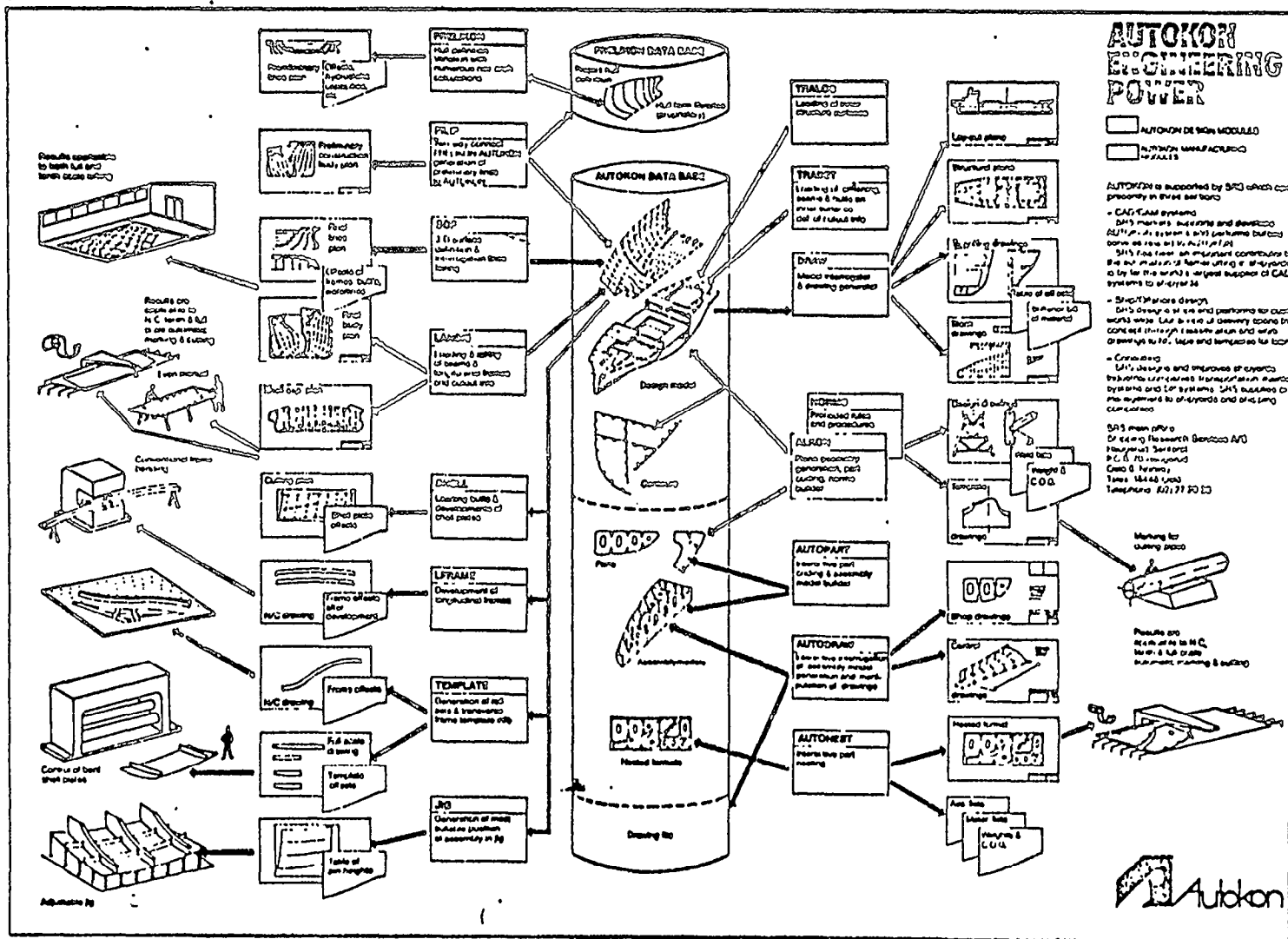


USING AUTOKON FROM EARLY DESIGN:  
RECENT EXPERIENCE FROM ACTUAL SHIP DESIGNS

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ABSTRACT

This paper includes a short outline of design modules; results of a 12500 TDW chemical carrier; economical comparison between the first project which was a 11000 TRW anti the last project of a 12500 TDW chemical carrier done in SRS utilizing design modules; and the results from a 128000 TDW oil tanker, from an early design stage, to use of AUTODRAW.



## TRALOS/TRADET/DRAW

### Features:

- o Definition of the main surfaces in the ship
- o Definition of cut-outs
- o Definition of profiles and stiffenings
- o Definition of plate seams and thicknesses
- o Simple input to the program
- o Complete list of profiles used on the surfaces
- o Easy updating of data due to topological description
- o Generation of detailed drawings of the surfaces, including profiles and seams

For classification, steel and work drawings the modules TRALOS, TRADET and DRAW are used. These modules are used together with the other AUTOKON modules and store the results in the AUTOKON database. The results are stored both geometrically and topologically, which means that the data are related to each other. By changing some data, you will automatically have all related data updated as well.

This special feature makes it possible to drastically reduce the hours needed for alteration of drawings. At the same time you will always have access to the latest edition of drawings, and these drawings will show the correct geometrical results.

The TRALOS module is used for definition of any internal longitudinal surface in the ship; The surfaces may be plane (parallel to the center line), curved with chamber and sheer, or twisted. Or the surface can be a combination of the above mentioned. TRALOS will handle any type of conventional longitudinal surface, unless it has to be faired. It can also handle inner surfaces connected to an unsymmetrical body plan. The programme can handle three main groups of surfaces depending on the transverse configuration of the surface. Horizontal surface (HSUR) defining decks, tanktop etc. which do not have any vertical lines. This may be used for symmetrical body plan with the same type of surfaces, but unsymmetrical bodyplan (WSUR), finally vertical surfaces such as girders or similar which do not have any horizontal lines, and long bulkheads (VSUR).

## TRADET

The module TRADET stores all the detailed data related to a TRALOS generated surface in the AUTOKON DATABASE, such as:

- 0 Profiles, beams and girders
- 0 Definition of all seams and butts describing type of joint, extension and related plate thicknesses
- 0 Definition of minor internal structures, including extensions and connecting surfaces
- 0 Definition of connections between surfaces with necessary identification and type of connection, such as open, water tight etc.

The profiles are split into relevant groups and will be identified with a profile number and on which side of the ship they belong. Profile orientation is established according to the "View" from which the profile is seen.

Joints between the various parts are called seams. The seams are also split into relevant groups and are identified in the same way as the profiles. In addition the thickness and type of weld is taken into consideration.

## DRAW

The DRAW module is used to generate drawings with different levels of detailing.

Scantling drawings which includes graphical lines of any structure penetrating the drawn surface.

If the penetrating profiles have been defined, the drawing will also include the cut-out contours.

Structural drawings which include information of the scantling drawings plus the graphical details belonging to the surface itself such as:

- o Stiffeners
- o Seams
- o Connections of minor and major parts
- o Inner contours

"windows" can be defined for detailing of the drawing. Symbols are added for the seams. Stiffeners and profiles, minor or major structures, will be drawn either with a continuous line or various dotted lines depending on the type of connection and profile location. (This side or other side).

#### Results from a 12500 TDW Chemical Carrier

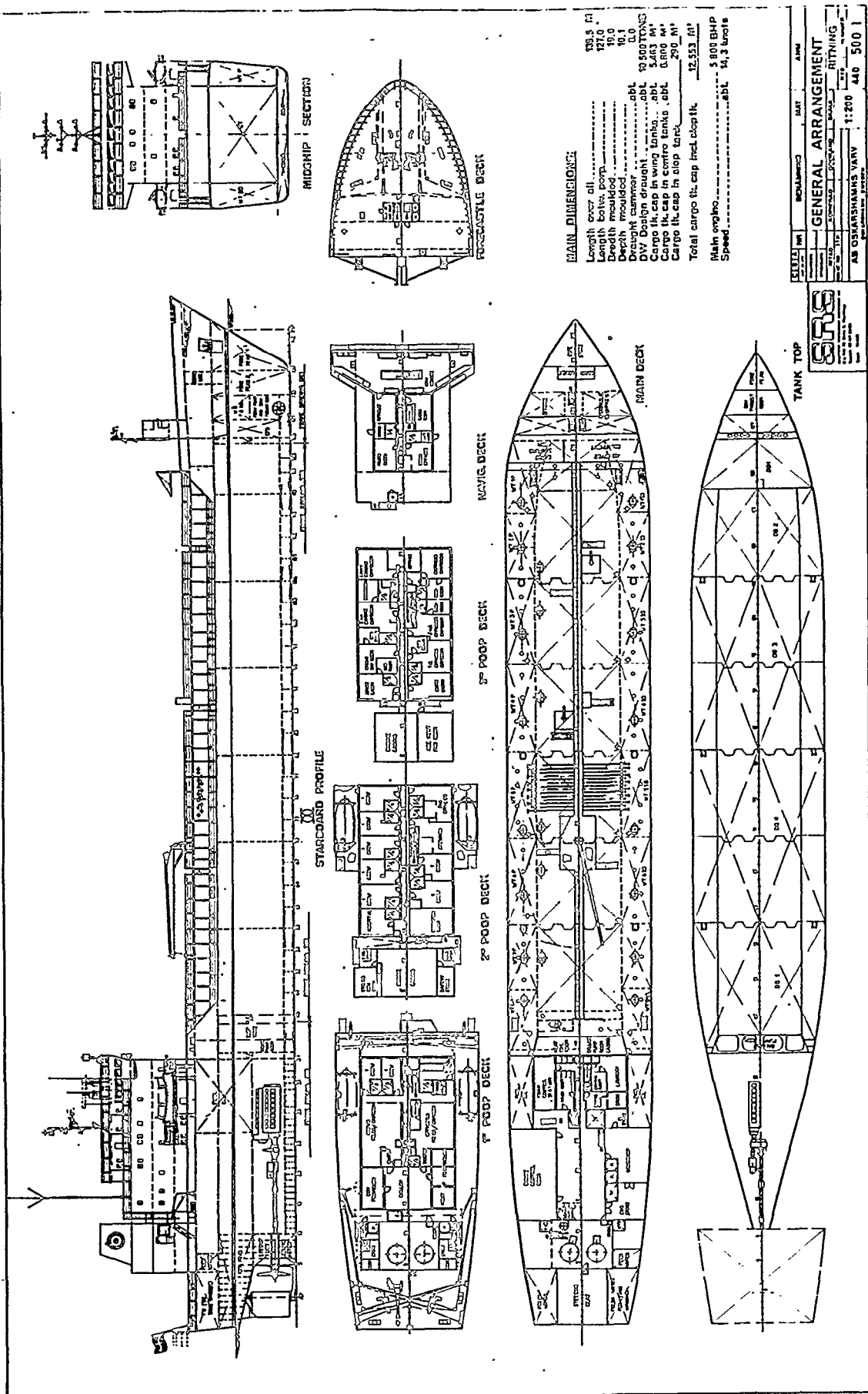
The work started for this vessel in January 1981, and very similar to a smaller vessel designed one year earlier.

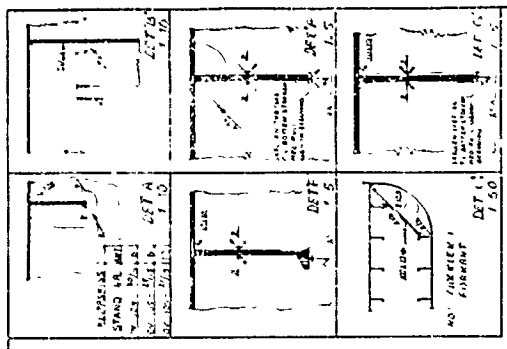
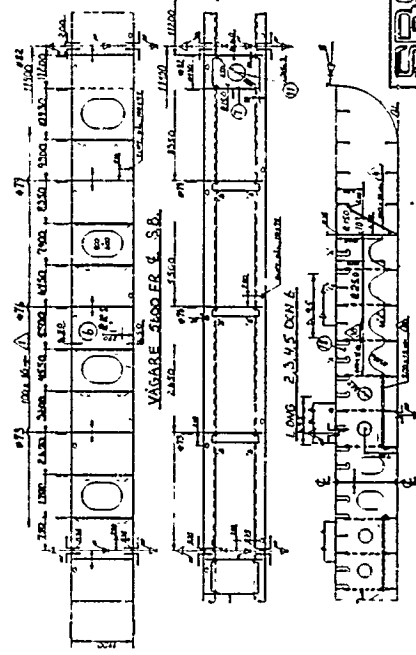
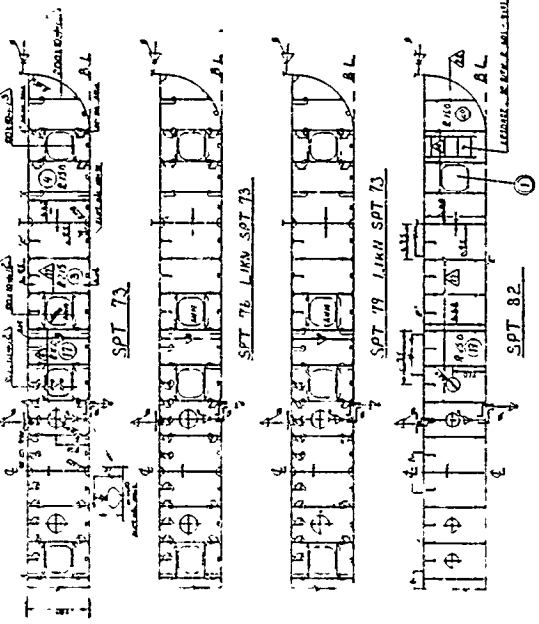
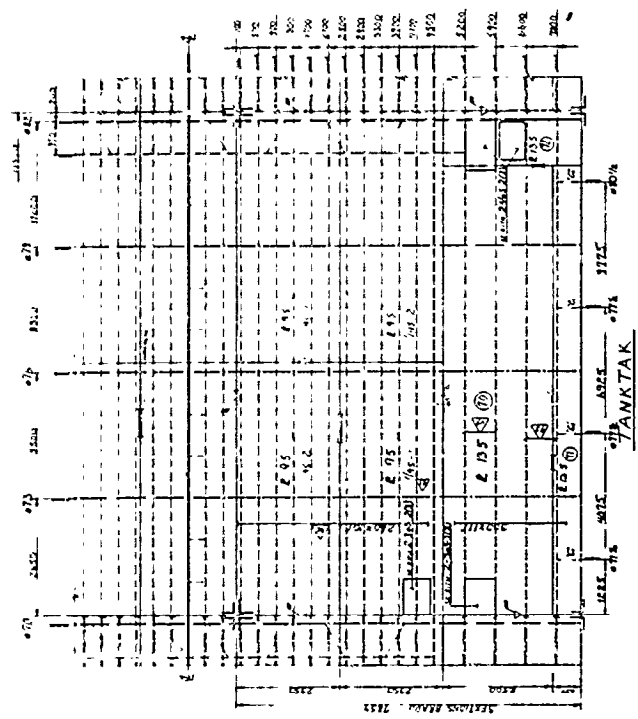
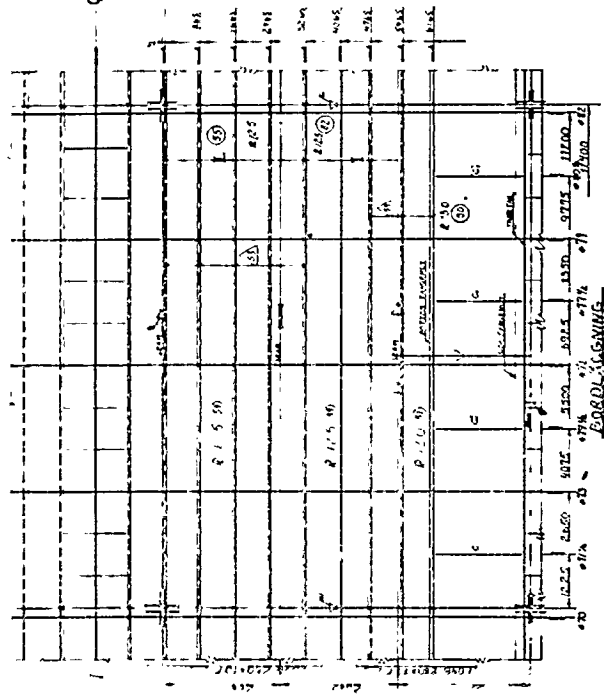
The scope of supply for this vessel was the same as for the first one.

Project drawings and documentation, classification drawings for steel, machinery, accommodation and outfitting.

Working drawings, Pipe diagram and pipe sketches.  
Complete lofting.

On the following pages, typical drawings can be seen. These types of drawings have not only been used by the steel people, but also machinery and outfitting departments have used these drawings for their purposes.





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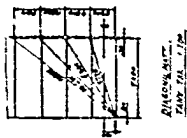
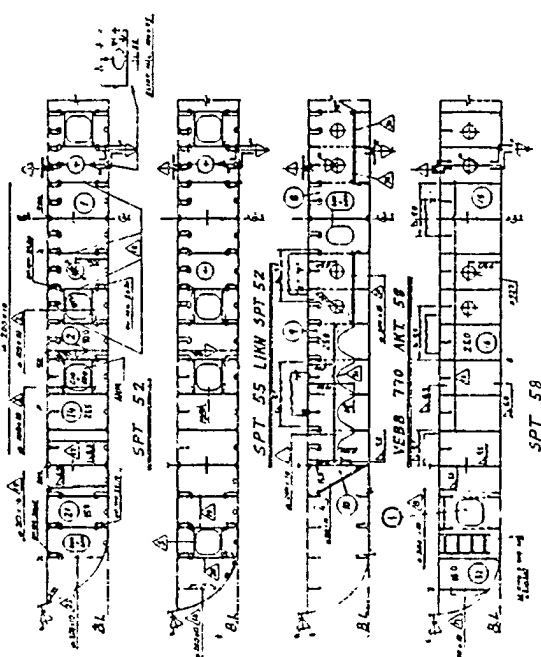


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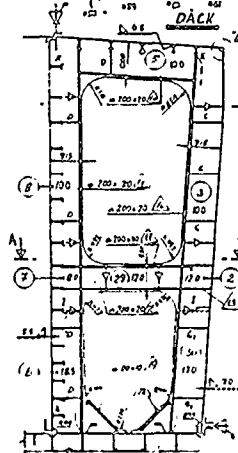
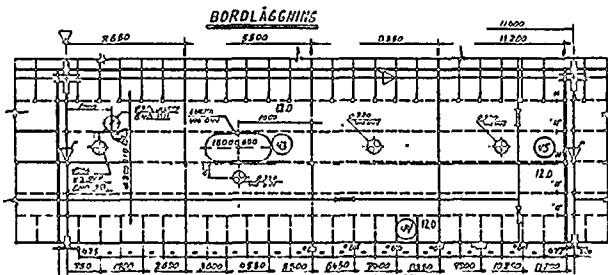
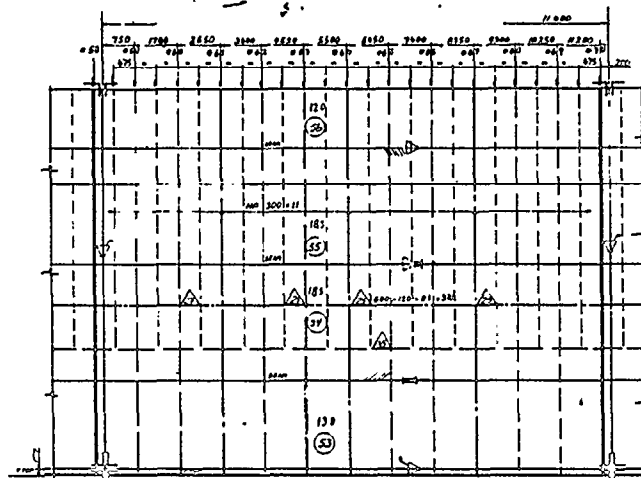




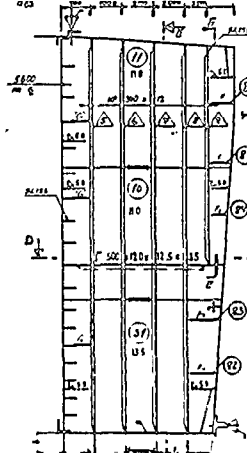


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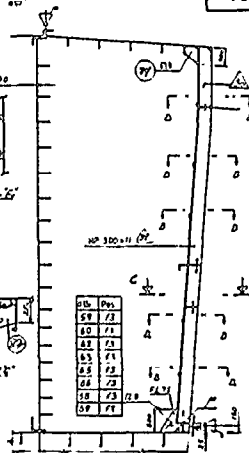
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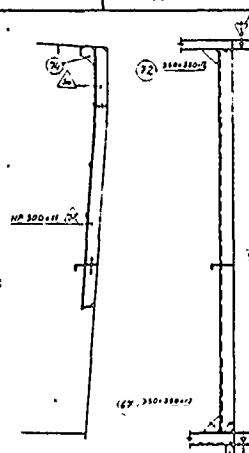
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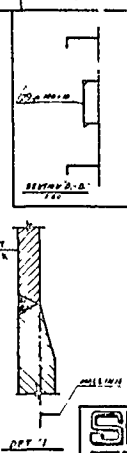
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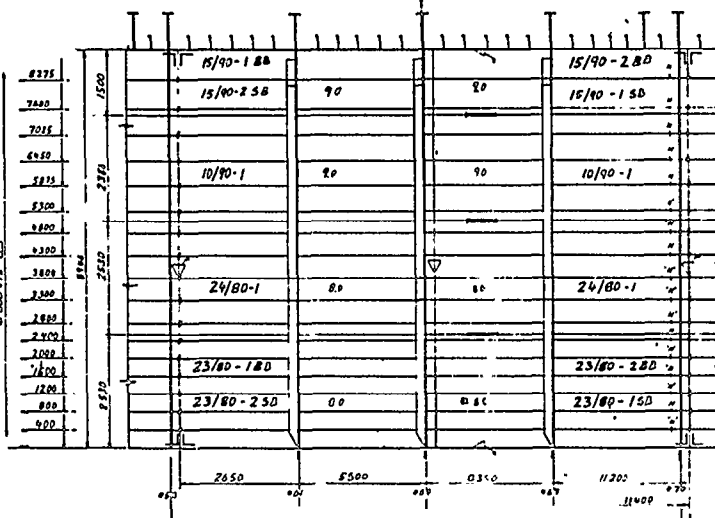
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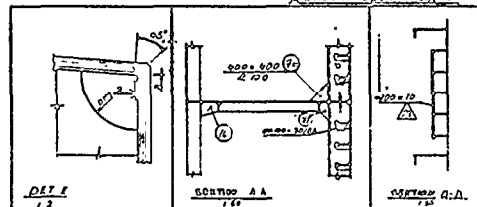
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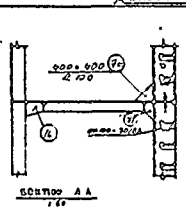
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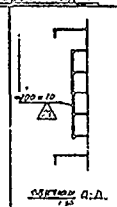
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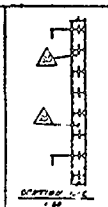
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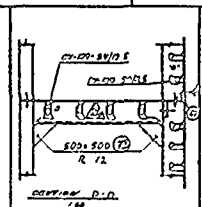
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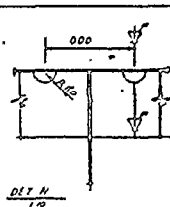
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SECTION C-C



SECTION D-D



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SPANT DISTANS 950 mm

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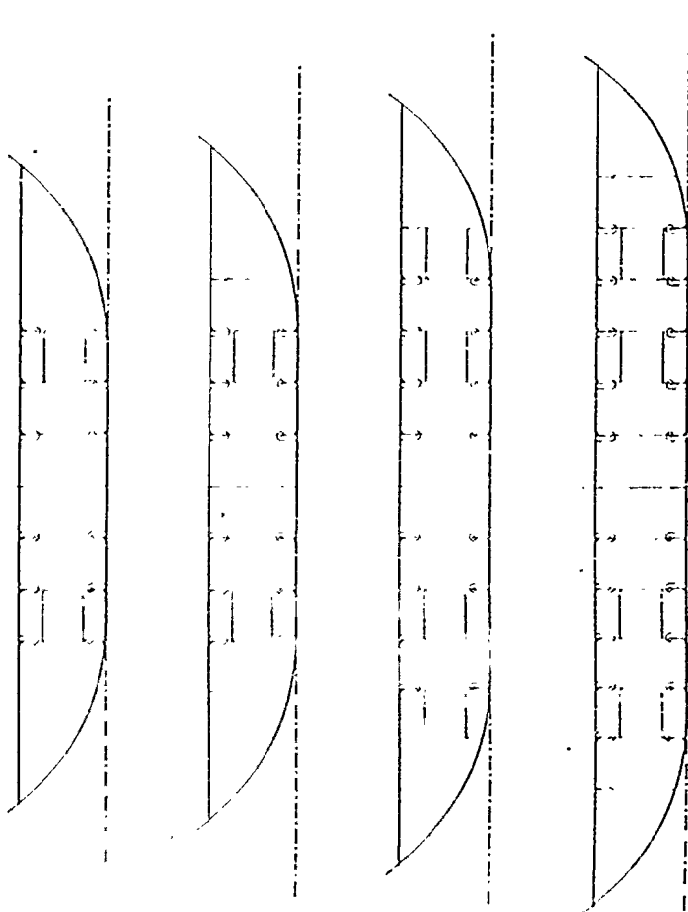
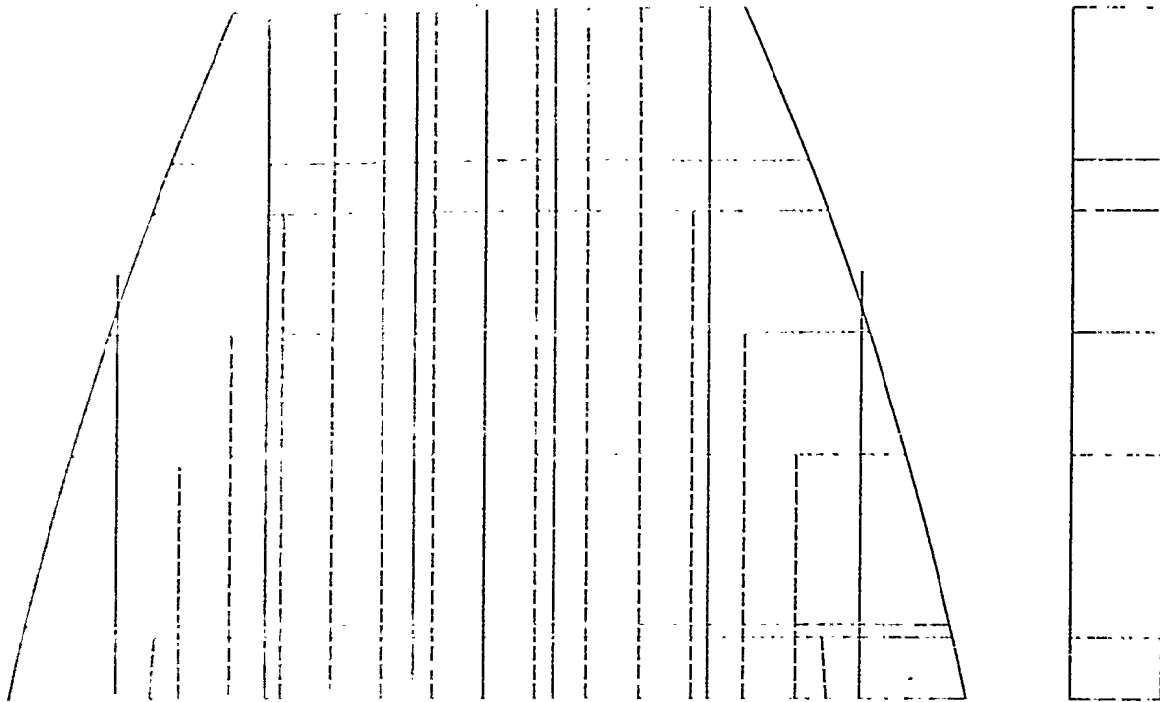
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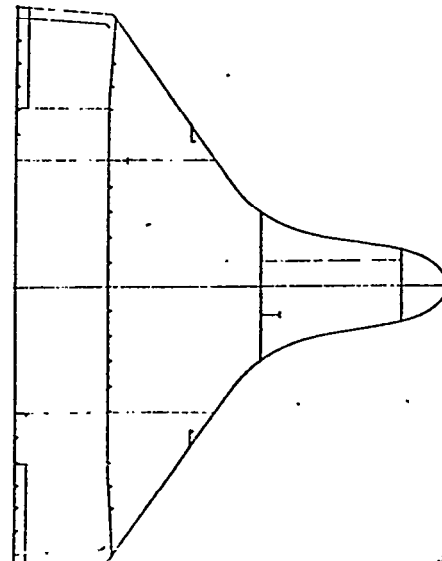
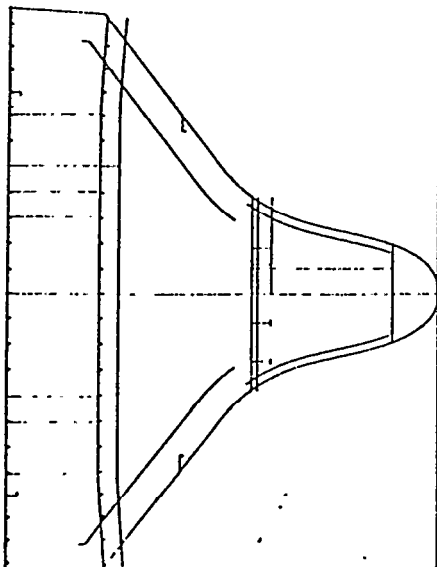
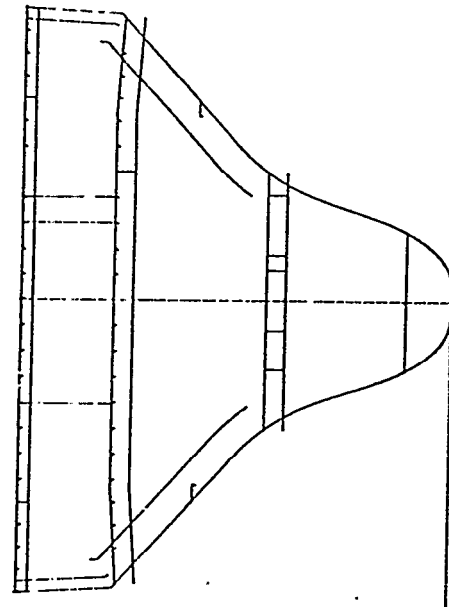
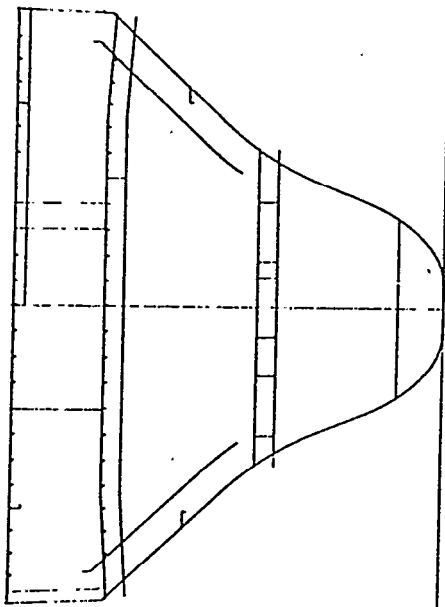
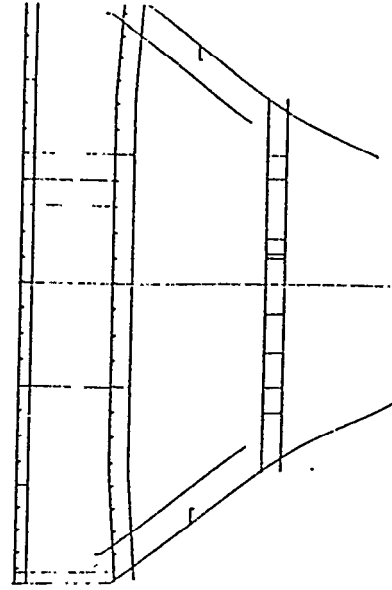
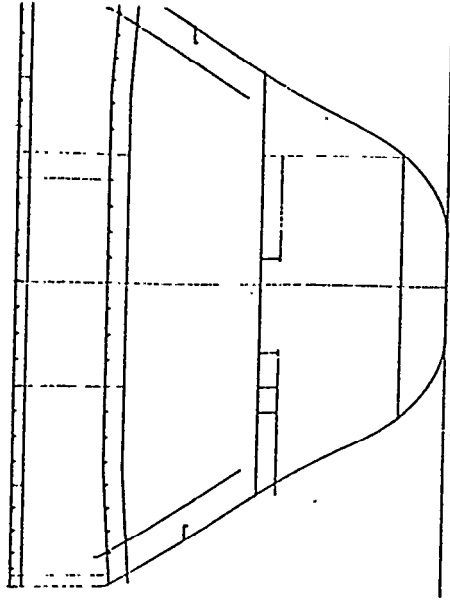
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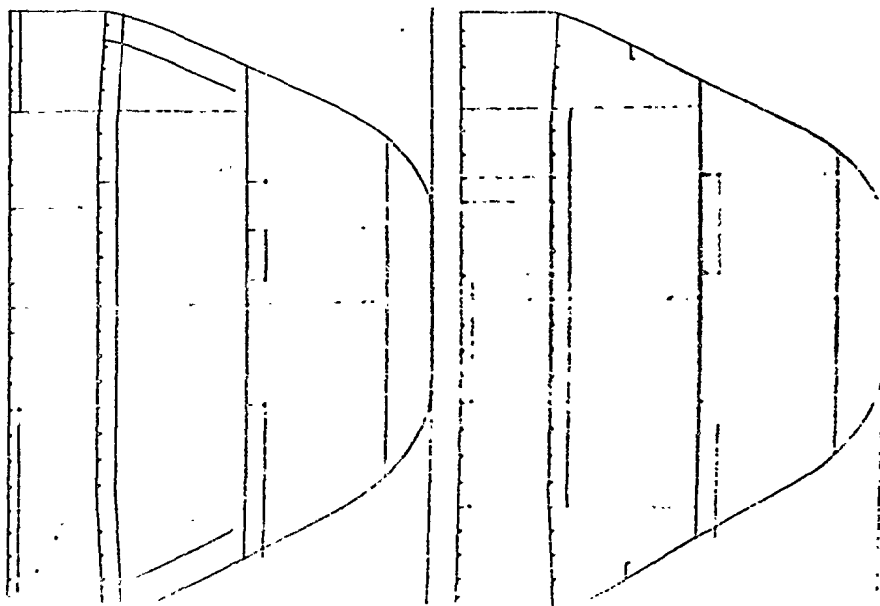
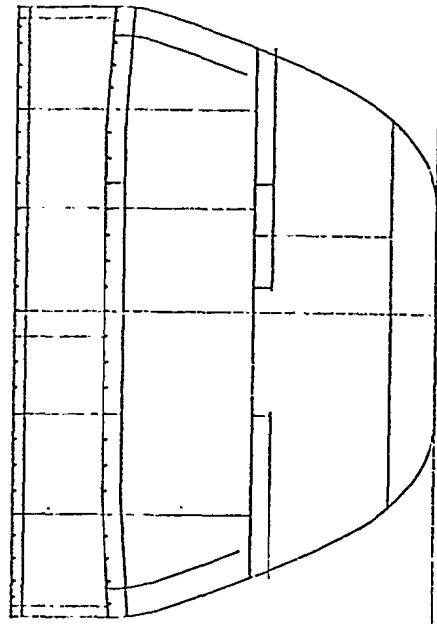
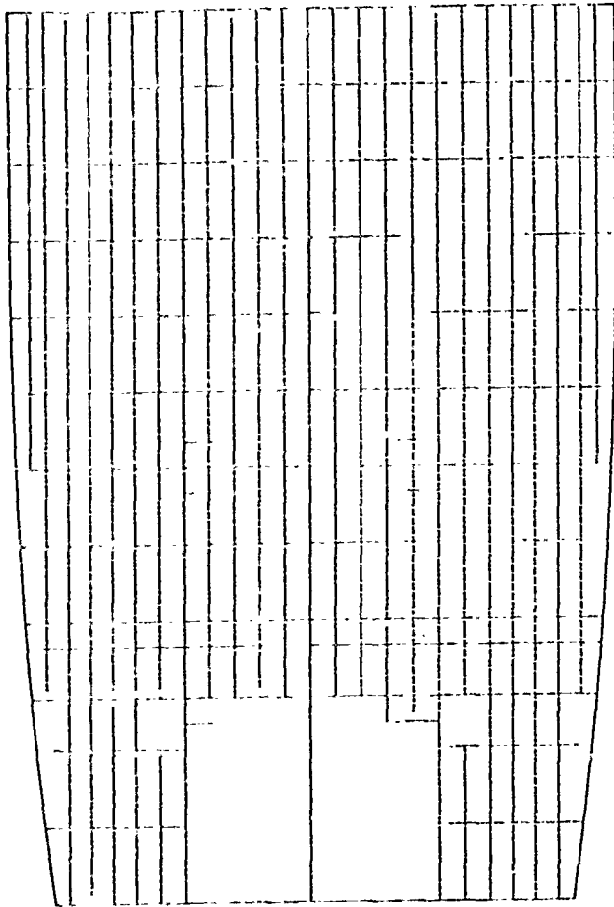
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Economical comparison between a 11000 TDW and a 12500 TDW  
Chemical Carrier.

	125000 mw	11000 TDW
Classification drawings	1450 hr 30%	2500 hr 36%
Working drawings	2700 hr 57%	3070 hr 45%
TRALOS/TFUDET	255 hr 5%	680 hr (400) * 10%
Material take off	465 hr 8%	600 hr 9%
Total	<u>4790 hr</u>	<u>6850 hr</u>

Diff: 2090 hr or 30% less manhours.

\* Since this was a pilot project 400 hr. direct waste getting the system working, and slow drawing machine.

On first project we had 16% reduction and 25% possible reduction if the system had run smoothly compared with traditional made drawings.

The second project we would have saved 34% if we had the same base of calculation as the first project, so 34% and 16% can be compared with each other.

Results from a 128000 TDW Oil Tanker,  
from an early design stage, to use of AUTODRAW.

The scope of work for this vessel were to deliver classification drawings.

To get a bodyplan for this vessel within time for our schedules, we had time to fair aft body, and fwd body, but we had to use preliminary lines from PRELIKON by FILIP. This meant we were able to start to create drawings for the complete vessel three weeks earlier. The total time spent on TRALOS and TRADET was about 60 hours.

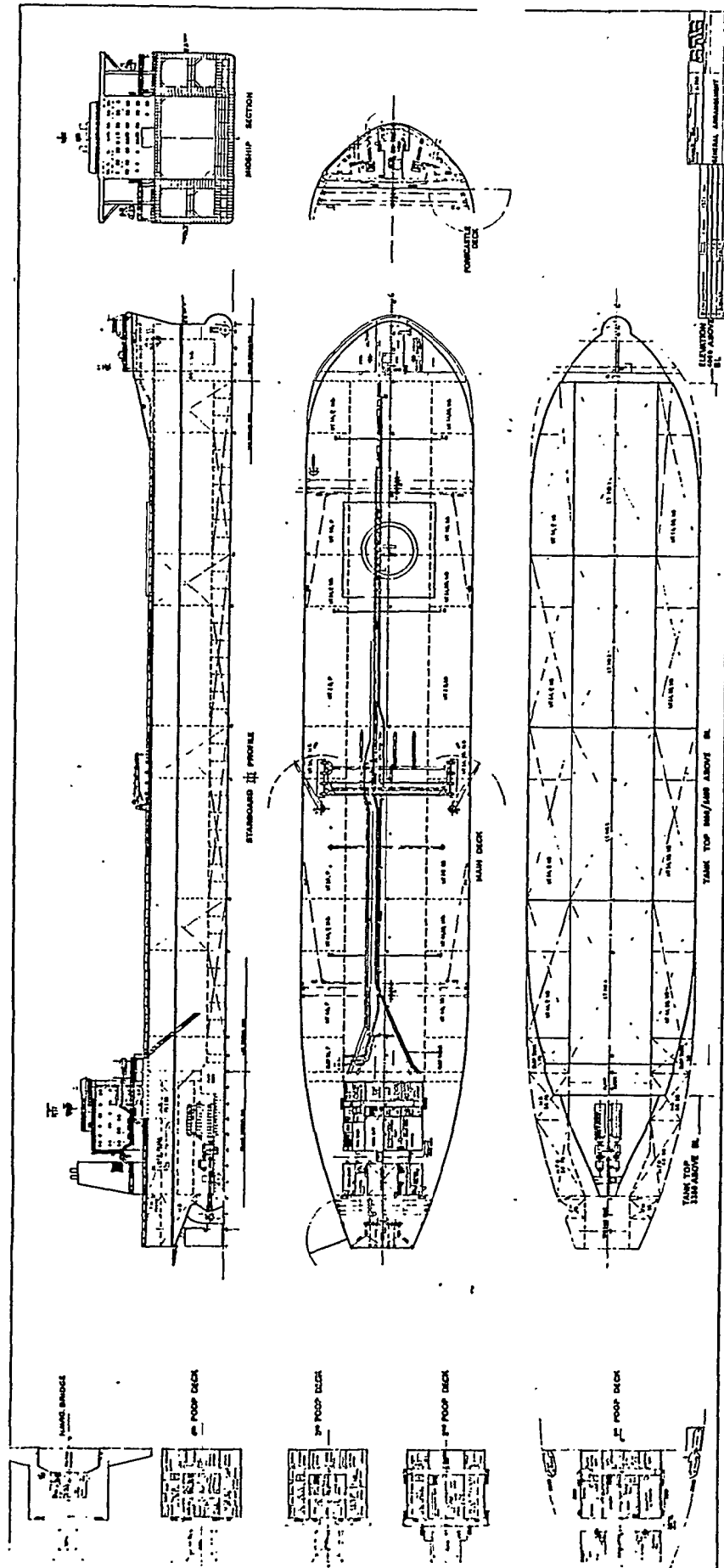
The reason for not spending more time on the designmodules, was simply that with this amount of input we got the greatest benefit out of the system compared with type of drawings to be delivered. Also to keep in mind that we were not going to do any working drawings or lofting on this vessel. If so, we would have done more work on the design modules.

Time spent on class. dwgs	2100 hours
Material spec.	430 hours

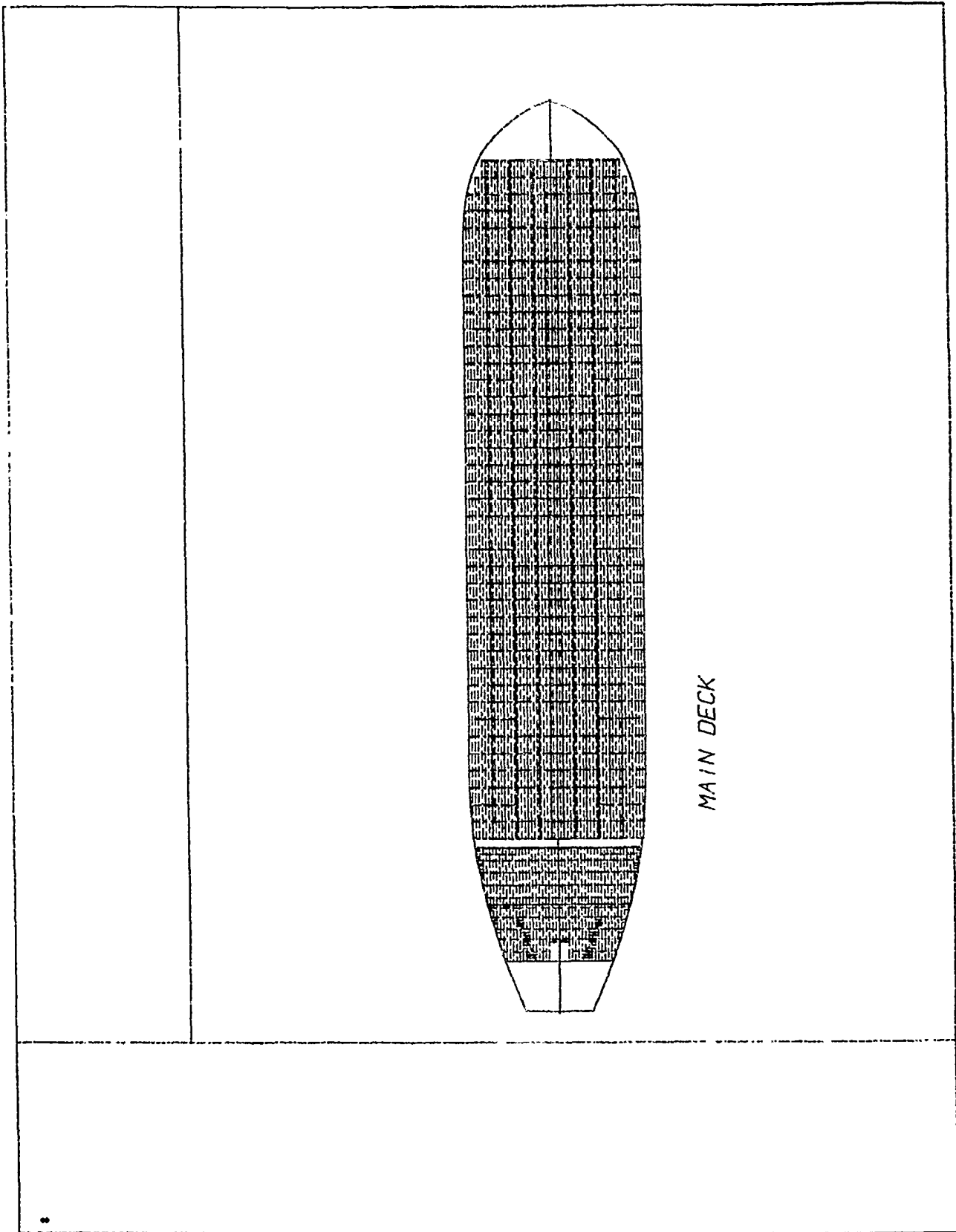
This excludes superstructure and rudder of the vessel.

Normal time for this type of vessel would be about 3000 hours.

This means about 25% saving on the class drawings.







The next step to save time in the drawing process, is to have an automation. for texting and symboles (details) in the computer. This can be done by taking the papertapes from Tralos, Tradet to Autodraw, and do the completion of the drawing in Autodraw.

This we have done with some drawings and the result for this seems satisfactory.

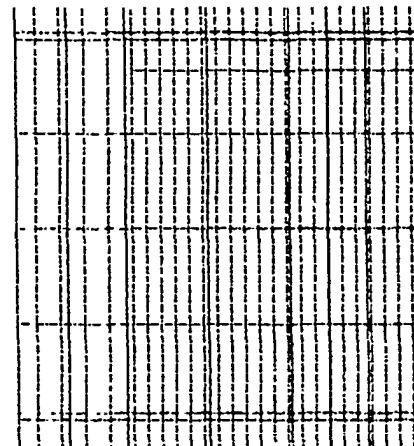
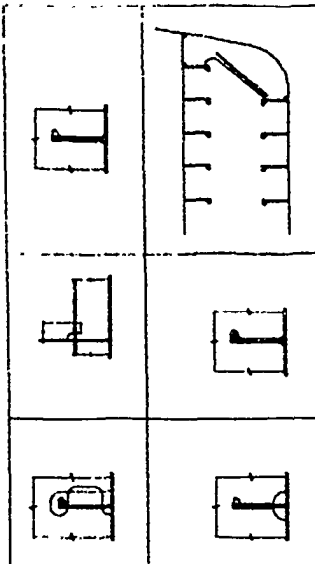
We have made a number of standard steel details which is used regulary, and placed them on the drawings.

The time spent for building up a working drawing, can be reduced considerably. As an indication we are talking about 15 - 20 hrs. to get a complete working drawing. Normal time for such a drawing is about 40 hours.

This means a saving of 50% for 62%.

This would also be valied for classification drawings, but the saving less. About 30% to 40%.

These reductions are of course dependent on the standard steel detail library available.



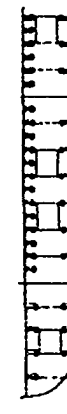
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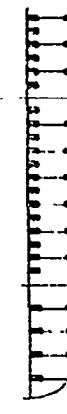
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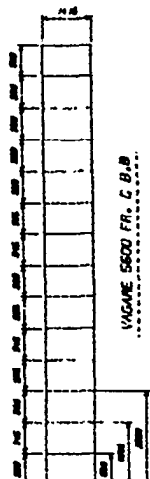
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SPT. 82

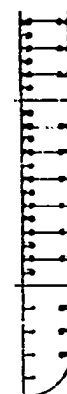


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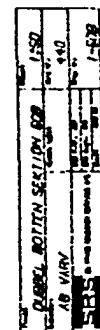


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JAPANESE SHIPBUILDING TECHNIQUES:  
SURFACE PREPARATION AND COATING--MATERIALS AND METHODOLOGY

Gerald, C. Soltz  
GCS Corrosion Consultants Inc.  
Howell, New Jersey

ABSTRACT

In this paper the Japanese and United States Shipbuilding Industries' coating systems and surface preparation and application methods are compared. The surface preparation and paint planning process as it relates to zone construction will be discussed in detail.

*A comprehensive report on Japanese Shipbuilding, which will expand on remarks given at this conference by Dr. Gerald Soltz and Mr. John Peart, should be available by late January, 1982.*

*Those interested in receiving a copy of this report should contact: John W. Peart, . R & D Program Manager, Avondale Shipyards, Inc., P. O. Box 50280, New Orleans, Louisiana 70150.*

Good morning .

The remarks I am about to make are based significantly on a recent trip to Japan, where John Peart of Avondale Shipyards and I toured a number of Japanese shipyards under the joint auspices of Avondale Shipyards and the Maritime Administration, as part of the National Shipbuilding Research Program.

Since returning from Japan, Mr. Peart and I have found that many people assume our trip was intended to learn all we could about Japanese efficiency -- an impression I'd like to correct, in order to set apart the real purpose of our trip from that much-abused term!

We're not against efficiency: but what could be worse, or less productive, than working very efficiently on something that shouldn't be done at all?

The factor we DID want to look at was the ability of the Japanese shipbuilding industry to combine high productivity with a notably respectable level of quality control.

"Efficiency" has something to do with this, of course: but so does technology; and operations planning; and work systems; and materials design; (and, of course, costs; and, inevitably, compromises).

The first factor I would like to focus on is PLANNING.

In Japanese shipbuilding, the PLANNING phase predominates. It is more wide-ranging, more methodical, more comprehensive, and worked out in much greater DETAIL than is usual in the U.S.

However, once the Japanese plan is set: it is MET.

What a Japanese shipbuilding plan calls for is what will actually be produced; and there will be very few "surprises" to worry about. Instead, you can pretty much count on the end result, the completed vessel, being satisfactory within the range of the original plan.

One trick to this may be that often the Japanese PLAN itself is not grandiose, its goal nothing more earth-shaking than the production of a vessel capable of a reasonable service life.

This goal, however, is one the Japanese achieve.

Just what procedures are involved in achieving this goal?

In the case of surface preparation and coating application:

1. All plates are primed automatically by machine, or supplied to the yard pre-primed by the steel mills.
2. Plates are then moved through normal cutting and welding procedures and built into sub-assemblies.
3. After sub-assembly, disc sanding of surfaces and wire brushing of welds is carried out. The resulting surface preparation will be about the best reasonably obtainable from mechanical cleaning procedures. The surface will be less than a top or "ideal" grade; but within its grade it sets a solid and respectable standard. It would be missing the point to observe that better results might have been obtained with sand blasting or sand sweeping; because we are talking about a Japanese STANDARD surface preparation plan, which simply doesn't normally call for those techniques.

This type of standard surface preparation, by the way, is sometimes referred to as ISC-B, where disc sanding and wire brushing procedures are carried out in way of burned areas. Here, too, the standard procedures account themselves very well, normally removing all rust and ship primer in way of burned areas.

After wire brushing and disc sanding as Standard Surface Preparation, what follows as Standard Coating?

A single coat of coal-tar epoxy is normally used in ballast tanks; additionally, in the case of ballast tanks, striping of edges and ratholes is standard in some Japanese yards, but not in all cases.

In addition to standard surface procedures, the Japanese also offer capability for higher-quality surface preparation of cargo tanks, and in some cases ballast tanks, when this premium quality preparation is requested by a shipowner. In such a case:

1. Disc sanding and wire brushing phase out, in favor of sand sweeping and/or sand blasting;
2. Full striping replaces edge striping;
3. Extra coats of paint application are specified beyond "critical areas" only;
4. Some "customization\*" of materials, work, or design may be designated (as, segregated product tanks.

Processes described so far are normally carried out in a three-stage procedure:

1. Overhead tanks blasted and primed to about 1<sup>1/2</sup> meters above bottom;

2. Stripe coats and top coats applied to these upper primed surfaces;
3. Staging used to reach these upper tank areas is then removed, and the lowest 13 meters of tanks are blasted, primed and coated.

These three stages are generally carried out in several tanks simultaneously, by the way -- with work operations planned so that the staging can be used in, or moved from, one tank to another sequentially: a sensible plan for efficient use of equipment.

In the case of this higher-standard surface preparation, the owner will of course pay a premium price for the upgraded materials and escalated procedures criteria he identifies.

It's sometimes said that the American MINIMUM shipbuilding standards are higher than those in Japan; however, the attention, precision and sophistication they bring to their highest-criteria shipbuilding plans would seem to indicate that their MAXIMUM standards can be well above ours.

One feature of the Japanese "Maximum Standard" which ought to be mentioned is that it is accomplished almost exclusively by sub-contractors -- specialists in coating procedures.

However I don't mean to set up an absolutely rigid distinction between a Japanese "Standard" shipbuilding plan and one that is more exacting (that I've just referred to as "Maximum Standard"). The distinction, while it exists, is not absolute.

The "Maximum Standard" that the Japanese can produce also hints at a flexible capability that can be used at times to selectively upgrade the "Standard" shipbuilding plan.



For example: while the "Standard" plan for ships' coating procedures in Japan has a number of compromises compared to what could be obtained in an overall "Maximum" shipbuilding plan, a Japanese shipyard may well designate critical areas WITHIN A "STANDARD" SHIPBUILDING PLAN -- but give these critical areas the benefit of "Maximum," or upgraded treatment.

In "critical" tanks, for instance, careful grinding down of all sharp edges precedes coating, in order to eliminate coating failure potential at those edges. In addition to rough edges, all sharp surfaces are also ground smooth.

In tanks designated for high-performance coating applications, pre-primed surfaces will be re-blasted to at least an SA 2.5 (and in face the results approach SA 3.0) throughout the tank before the blasted surfaces are then re-coated with holding primer of approximately 50-microns thickness.

Other features of the Japanese "Maximum Standard" shipbuilding plan:

1. Some system of dehumidification is normally used throughout these blasting and coating procedures;
2. During blasting stages, at least one of the major Japanese sub-contracting firms uses only reusable steel shot, rather than expendable grit. Since this reduces dust problems and materials costs at this stage of surface preparation, the particular sub-contractor had reason to be well-satisfied with the results obtained.

Where coating materials are concerned, the Japanese have recognized the importance of choosing a good pre-construction primer, since a well-selected primer is crucial in achieving both reasonable coating standards, and high productivity. It follows, then, that there are logically coating materials SPECIFICATIONS, or specific qualities Japanese shipbuilders find desirable in pre-construction primers. These qualities include:

- Ease of application
- Optimal handling time
- Quick hard-dry time (1-4 minutes)
- Anti-corrosivity (7-9 months)
- Good adhesion to steel substrate
- High resistance to solvents and chemicals
- Weldability (Should not generate pits or blowholes or affect strength of weld)
- Reasonable flame cutability (Should not slow cutting processes)
- Heat resistance (Minimally damaged by cut/weld processes)
- Low toxicity, few polluting agents (No heavy metals)
- Flammability safety
- Reasonable cost

In Japan, by the way, we observed that pre-construction primers and top coats are developed by paint companies in response to requests from the shipyards! This user-supplier relationship seems to result from a closer, more integrated working arrangement than is normally seen between U.S. shipyards and American paint companies. The Japanese way of doing it, however, would seem to offer a number of obvious advantages for shipbuilding productivity.

What is the "bottom- line" result of the Japanese system where shipbuilding productivity is concerned?

Methods discussed here have enabled Japanese to reduce the man-hours required per square meter of surface prepared and coated to less than .1 man-hour per square meter.

Maximum time normally required was about .4 man-hours per square meter (in slop tanks).

-- Overall average man-hours required for the "Standard" shipbuilding plan varied between .05 and .1 man-hours per square meter throughout a given vessel.

I feel strongly that the issues just outlined certainly call for more in-depth examination: all phases looked at in more detail; key processes quantified by cost analysis; and the overall demonstrable utility of Japanese and American shipbuilding systems further compared.

THE IMPLEMENTATION OF PRODUCTION ENGINEERING TECHNIQUES  
AT NORFOLK SHIPBUILDING AND DRYDOCK CORPORATION

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Les Flora  
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ABSTRACT

Norfolk Shipbuilding and Drydock Corporation was about to start production of a floating dock to their own account. Design drawings were obtained from a naval architectural consultant. Norshipco was aware that the information on the design drawings had to be transferred to working drawings and, where possible, the producibility of the structure improved. The paper describes how this task was carried out, the drawing formats used, and the structural and outfit changes made.

## 1: INTRODUCTION

Norfolk Shipbuilding and Drydock Corporation (Norshipco) is a medium sized shipyard occupying some 180 acres, with a total workforce of approximately 3,500.

Whilst primarily a very successful and modern repair facility, new construction of small, specialized vessels has been undertaken over several years. With the success of the repair and overhaul activities any new construction work was, for the most part, an extension of repair techniques. This was reflected in planning methods and information generated for production.

While of excellent quality and workmanship, new construction contracts of late were not as financially successful as the company had anticipated and it was decided that if new construction was to remain part of the company activity a way had to be found which improved performance, reduced costs and delivered completed work on time. The most likely areas where this could be achieved was firstly production methods and secondly production information which was linked to the methods agreed.

## 2: THE TEST CASE

Late in 1980, the new construction group of Norshipco was faced with the task of constructing a 200 ft. steel floating drydock to its own account. The design had been previously contracted to an independent marine consultant and budget figures for material and manhour costs were prepared and submitted to management for approval.

Upon authorization, work was started on the drydock in January 1981, using the design information received from the consultant for production purposes. The new construction group realized that if a greater financial success was to be achieved changes were necessary both in the presentation of technical information and in production methods, but were unsure as to the approach and direction to take.

At this time, the UK based company, A & P Appledore Limited, were conducting a facility development study and it was suggested that one of their ship production engineers could assist in developing and establishing production methods and technical information. This offer was accepted and in mid February 1981 the implementation of Production Engineering techniques in new construction was started.

## 3: SCOPE OF WORK

With the drydock as a test case, the aim was to take the existing drydock design and engineer its construction to give the most efficient use of manpower, equipment and material within the existing facilities,

the objective being an increase in productivity and a reduction in costs.

#### 4: REVIEW OF CURRENT PRACTICES

Before the problems could be solved, they had first to be identified and possible areas for improvement found by:

- a) Revieting the production processes currently being employed
- b) Reviewing the nature and format of technical information being used by production

##### a) Production Prosesses

These were examined on an informal basis by spending time talking to all the various levels of personnel involved and by observing established prastices. From this a number of things became apparent.

- 1) The detailed coordination of work between trades was not considered, resulting in additional manhours and material being used for rework, such as structure being removed or changed at the berth during outfitting.
- 2) A lack of faith in the accuracy of technical information resulted in an excess of "green" material requiring double cutting, usually at the berth,
- 3) While an erection sequense had been established in the early stages of the contract the detailed assembly process had not been defined. This resulted in access difficulty and difficulty in maintaining dimensional control, both involving wasted manhours and materials.
- 41 The lack of staged dimensional control checks throughout the production sequence resulted in an assumulation of errors requiring corrective rework in erection.

##### b) Technical Information

The initial study of the design drawings revealed why problems were being encountered in production, whilst the design drawings ensured the structural integrity and operational efficiency of the drydock, they did not consider actual producibility. In addition, the drawings themselves had a number of shortcomings.

- 1) The level of detail of information contained on drawings varied. In some Cases, they were over detailed to the point of chaos, in

other cases they were outline diagrams only.

- 2) Information was inconsistent from drawing to drawing. For example, sea chests shown on the structural drawing were shown in different locations on the piping drawing.

Two other factors also became apparent:

The use of design system diagrams for material allocation and ordering resulted in excesses of material.

The lack of a detailed material coding system resulted in large quantities of scrap material and in some cases incorrect allocation.

During this review phase, it was confirmed that the problem of using general design drawings in production and allowing individual trades to overcome their particular problems as they arose was a significant contribution to the amount of rework, trade interference and change orders encountered.

## 5: APPROACH

From the reviews of the Production Processes and Technical Information, it was apparent that the majority of the problems being encountered could be attributed to two major causes:

- 1) The application of repair production techniques to new construction
- 2) The use of basic design drawings for production purposes

By applying production engineering techniques to both the production methods and by matching the production information, to the methods, difficulties in access, fit up, assembly, trade interference and coordination, etc. could be solved before actual work started. The approach was in two stages:

- a) The production engineering of the basic design.
- b) The development of a production orientated drawing system which would align with production methods.

### a) Production Engineering - Basic Design

This involved a detailed study of the design drawings from a producibility point of view. Consideration was given to:

existing facility capability  
work breakdown structure  
natural work orientation  
assembly and block relationships  
accessibility  
standardisation and rationalisation  
of piece parts and materials  
advanced outfitting of steel structure  
working practices

Figures 1 and 2 show sections from the steel structure and ballast system design drawings, indicating areas where unnecessary or difficult work would have occurred if production had followed the design drawings.

Figures 3 and 4 show the same areas engineered to overcome the difficulties. This was incorporated into the general arrangement drawings, which is the second level of drawing.

Figure 5 shows what had been the intended erection sequence and breakdown together with the associated difficulties. Figure 6 shows the modified erection sequence and breakdown which overcame the difficulties.

#### b) Production Orientated Drawings

Having prepared the block breakdown, General Arrangement and Composite Drawings incorporating the changes, brought about by applying Production Engineering principles, we further studied the step by step assembly, outfitting and erection of the dock. The system used for transferring this thought process from the Production Engineering Section to the rest of the yard was through using a Production Orientated Drawing System.

Figure 7 shows the first stage of this system. Dividing the dock into Structure Groups and then into blocks in the Block Breakdown, each block was further analyzed in a structure group and like assemblies identified to form the Block Assembly Analysis. From the Block Assembly Analysis further study into the most convenient process of block assembly, integrated pre-outfitting, lifting and turning operations provided the Block Process Engineering, Figure 8. At this point in time, the drawings that have been produced are purely a method of transferring the thoughts of how the Production Engineer has arranged the structure in the General Arrangement drawings for ease of assembly.

From the Production Engineering drawings, the detail drawing office then prepared work stage drawings. Each drawing reflects exactly the work to be done at each stage of the assembly process, together with information for checking the dimensional accuracy. Drawings are produced for each different assembly in the orientation to be used on the shop floor. The method in which the drawings are issued to production can therefore be used to control the production process. For example, using a batch production process all like assemblies, say stiffened panels, belonging to the same structure group may be required to be produced consecutively. By issuing only the Panel



Assembly drawings, the production shops only have sufficient information to produce panels. This control prevents any unauthorised intervention in the production schedule. By parallel development of steel and outfit drawings in this manner the maximum benefit of advanced outfitting can be achieved. In this way, work package information was used to schedule production processes.

For piece part generation, standard sheet formats were developed for each individual machine and operation containing only the information required to produce the parts and set up the machine.

To enable the system to function effectively, a coding system was developed to reflect the assembly process, i.e. piece part coding, assembly coding and block coding. Figures 9 to 15 show photographs of the actual parts and assemblies produced and the information format provided to the shop floor. The benefits from the implementation of this system are:

- a reduction in labour manhours by eliminating misinterpretation of drawings

- a reduction in material cost by providing an accurate material ordering and allocation coding system

- the elimination of rework due to trade interfaces

- improved dimensional control

- an easy and reliable planning and scheduling system identifiable with production processes

- the basis for recording performance and creating more accurate estimating data

## 6: EFFECT IN TEE TECHNICAL OFFICE

Because design drawings were used by production and additional requirements were largely subcontracted, the permanent drawing office staff at Norshipco was small and only consisted of three draftspersons, controlled by a contract supervisor.

At the beginning of the implementation program, one draftsman was appointed to work with the A & P Appledore Engineer, organizing the technical information for the drydock. In the initial stages of the program, with production of the drydock in progress and limited technical staff available, it became obvious that if the implementation of production engineering techniques was to be successful either an increase in technical staff or a slowing of production was necessary. Realising this, the management decided that an increase in staff was unacceptable and production was slowed for four weeks to allow the technical information format to be developed. This was a bold decision to make and demonstrates the commitment of senior management which is so important to the success of such a project. When production resumed

normal working, the technical information format and approach had been agreed and the major general arrangement drawings incorporating production engineering principles were complete.

A progressive restructuring of the technical section took place over the following months. Two members of staff were recruited from other sections of the technical office to form the Production Engineering Section. This small group controls the program and the development and issue of technical information to production. As other drawing office staff became available, they were transferred to the drydock project. At the end of May 1981, a total of four permanent staff were engaged on the drydock project.

The limited period given to the implementation program did not allow any formal training of technical staff or explanatory talks to production. Through a series of structured but informal discussions and on the job training, the technical staff became aware of the requirements of the technical system. Similarly, discussions with the various levels of production and management personnel allowed the system to develop to provide the required information for all departments.

The practice of subcontracting any additional drawing requirements from the design information made the assessment of increased drafting manhours difficult. However, the implementation of a similar system in a already efficient European shipyard did show an increase of 15% over traditional drawing practices, with a corresponding 10% reduction in production manhours.

The implementation of this type of technical system does require an increase in lead time before production start but the reduction in production time achieved does give a reduction in the overall contract time, employing similar manning levels.

## 7: EFFECT IN PRODUCTION

The drydock is the first yard project at Norshipco to use this system. At this time, the drydock is approximately 40% complete. The labor cost and figures to date are extremely satisfactory. Direct benefits due to the implementation of production engineering techniques proposed by A & P Appledore are now being realised by Norshipco in terms of reductions in both labor manhours and materials costs while maintaining the production program.

Labor manhour usage is currently running at about 50% of the original estimate for the dock construction. It is expected that at the completion of the contract the total manhour budget will be less than 70% of the original estimate, a reduction of 30% in production manhours. The reduction in production manhours can be directly attributed to the implementation of production engineering and production orientated drawings. There has been a significant reduction in trade interfaces and rework. The attitudes of the labor force have been much more positive, as they are

now furnished with clear concise information which relieves them from the task of drawing interpretation.

While a substantial reduction in production manhours was expected, a reduction in direct material costs came as a pleasant surprise. The parallel development of a detailed stage by stage coding system providing precise identification for ordering and allocation of material reduced the amount of waste dramatically compared with previous contracts.

Other: substantial material savings were made during the initial stages of production engineering. For example, by considering structure and piping as a whole reduced the amount of ballast main piping required in the bottom structure alone by over 100 ft., a saving in material costs of \$10,000.

Nora and more benefits are being realized due to the implementation of this type of technical approach. The benefits are not always as direct as labor and material saving but a more reliable scheduling system increases the confidence of forecasting at the corporate level. Coding, standardization and rationalization facilitate batch ordering and storage systems allowing a more efficient use of space. Identifying the construction sequence allows a more efficient use of service trades such as cranes, riggers, etc, assuring better control and reduction of overhead costs.

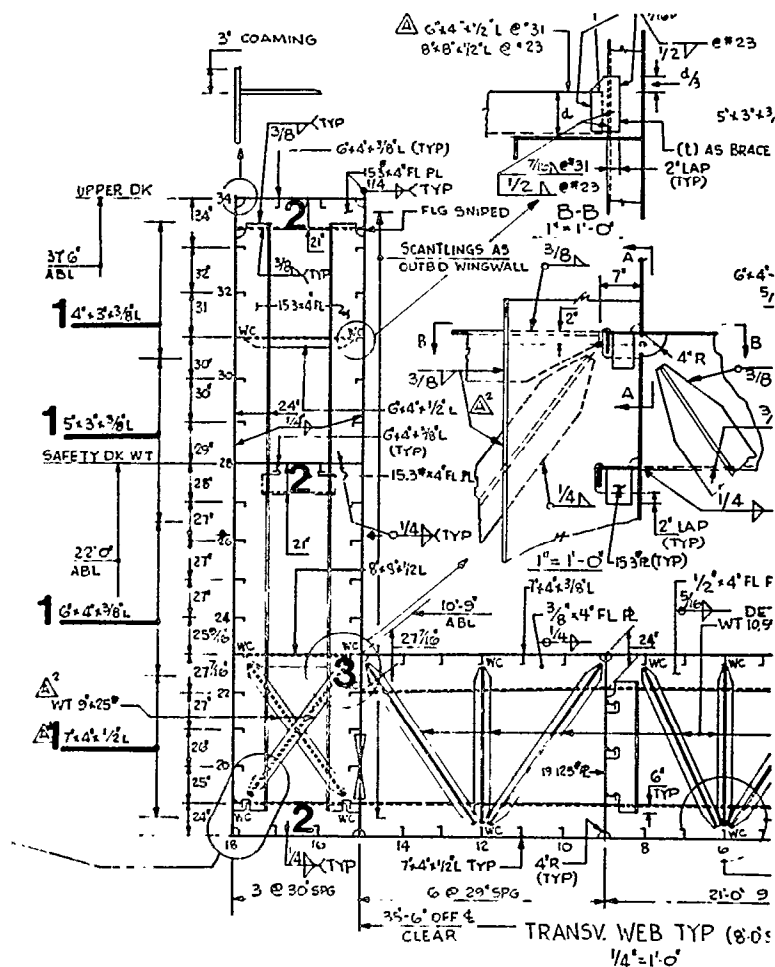
Another long term benefit is the accumulation of an accurate data base for estimating. By including weight and joint length information on the production drawings, records are being kept regarding manhours spent on assembly types. Together with the machine operation formats and production data a solid base is being built up for future contract estimating directly related to the actual performance and limitations of the existing facility.

The original estimate for the cost of the drydock was submitted on the basis of past performance in new construction. At this time, approximately 7 months from the start of the implementation of production engineering techniques the total cost of the drydock will be approximately 20% lower than the original estimated cost without any capital investment in new equipment or additional labor.

We feel that the implementation of this system in new construction is proving to be successful enough to warrant its current expansion into the field of naval and commercial repair.

The conclusion that can be drawn from this practical example is that the implementation of production engineering techniques, improved production methods and a technical information system aligned to the needs of production increases the requirement for technical expertise. However, if this is well managed and directed, a significant reduction in production time and costs can be achieved along with an improvement in quality of workship and increased job satisfaction to all concerned.

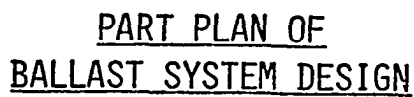
- ① Non Rationalisation of Stiffener Scantlings
- ② Non Standardisation of Piece Parts
- ③ Misalignment of Moulded Line due to Lap Construction



PART PLAN OF  
STRUCTURAL DESIGN

FIGURE 1

- ## ② Excess Material in Pipe Routing

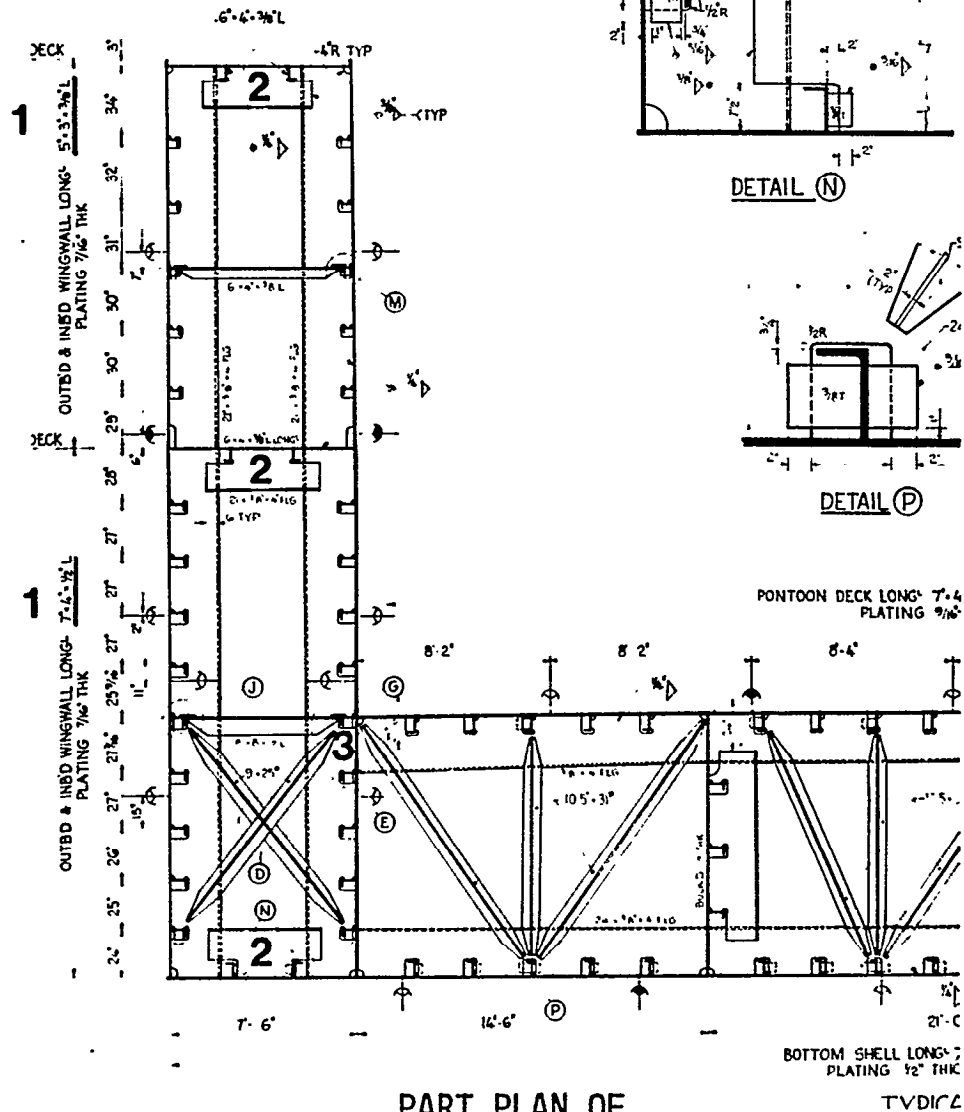


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① Rationalisation of  
Stiffener Scantlings

② Standardisation of  
Piece Parts

③ Change in Lap  
Construction to  
Provide Continuity  
of Moulded Line



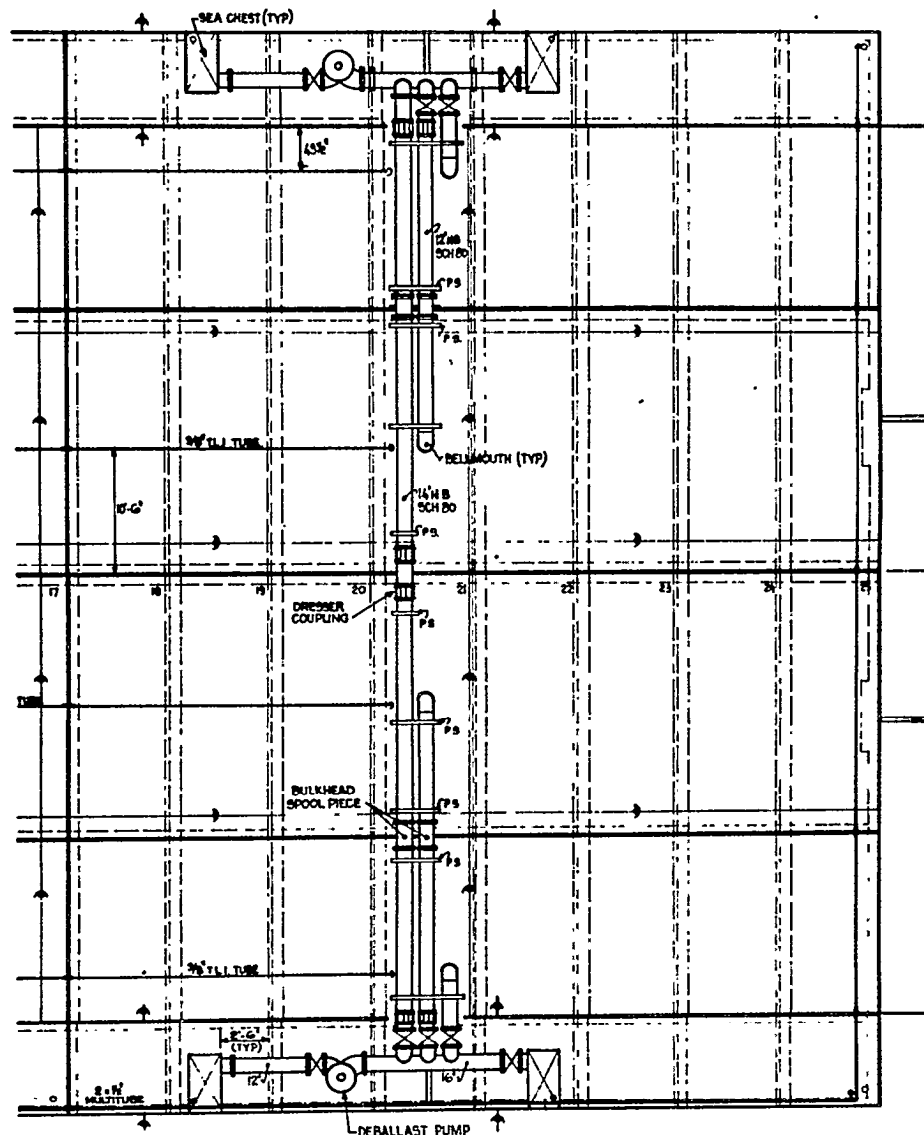
PART PLAN OF  
STRUCTURAL ARRANGEMENT AFTER  
PRODUCTION ENGINEERING

FIGURE 3

① Consideration given  
to Structure Arrange-  
ment and Block Breakdown

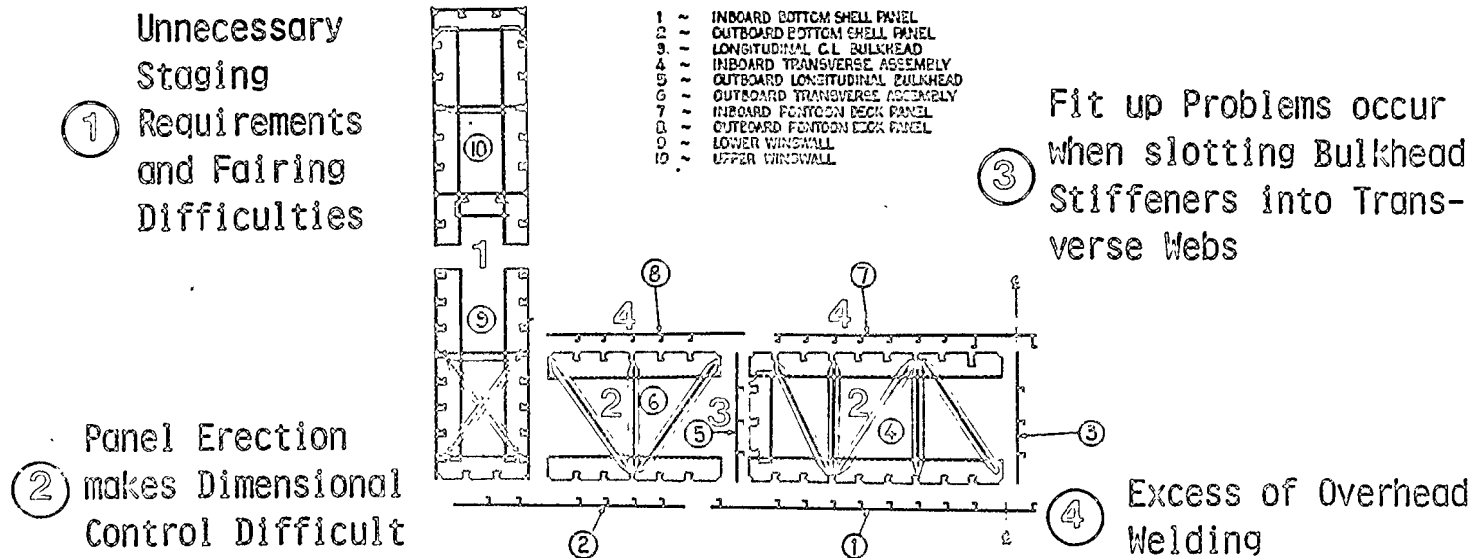
② Elimination of Excess  
Material by change in  
Pipe Routing and  
Arrangement

③ Pipe Arrangement  
changed to allow  
Modulisation and  
Pre-Outfitting

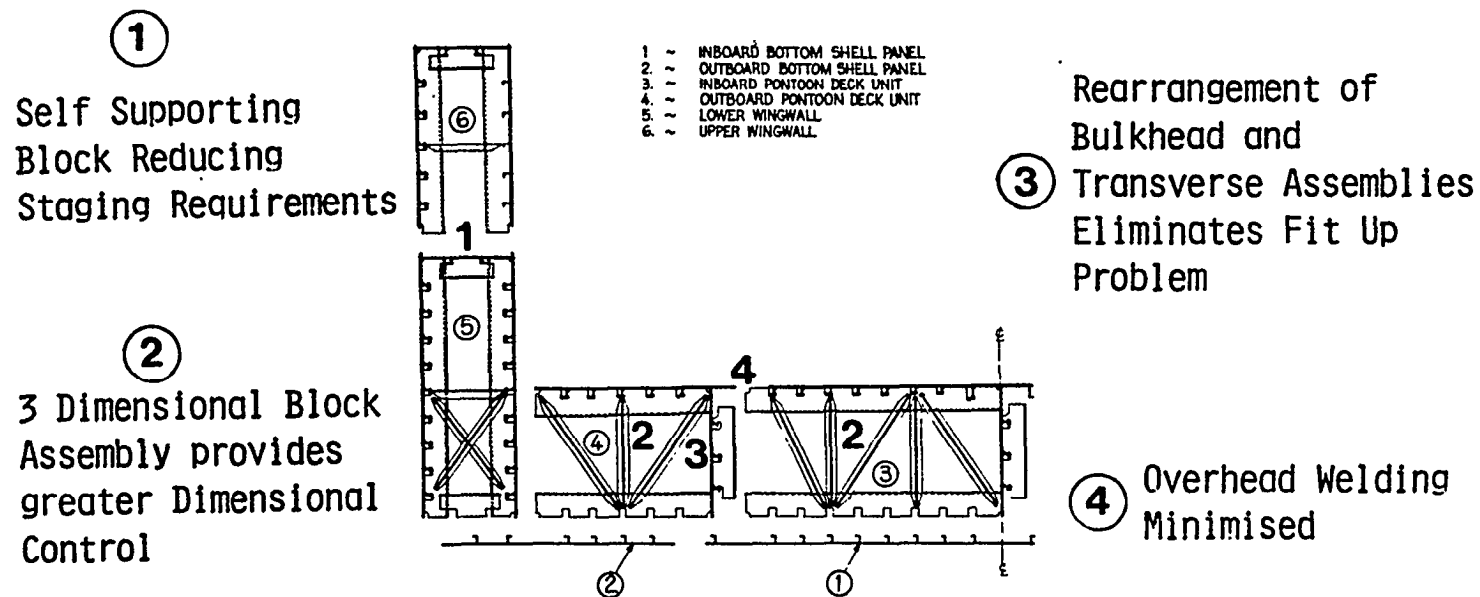


PART PLAN OF  
COMPOSITE ARRANGEMENT  
AFTER PRODUCTION ENGINEERING

FIGURE 4



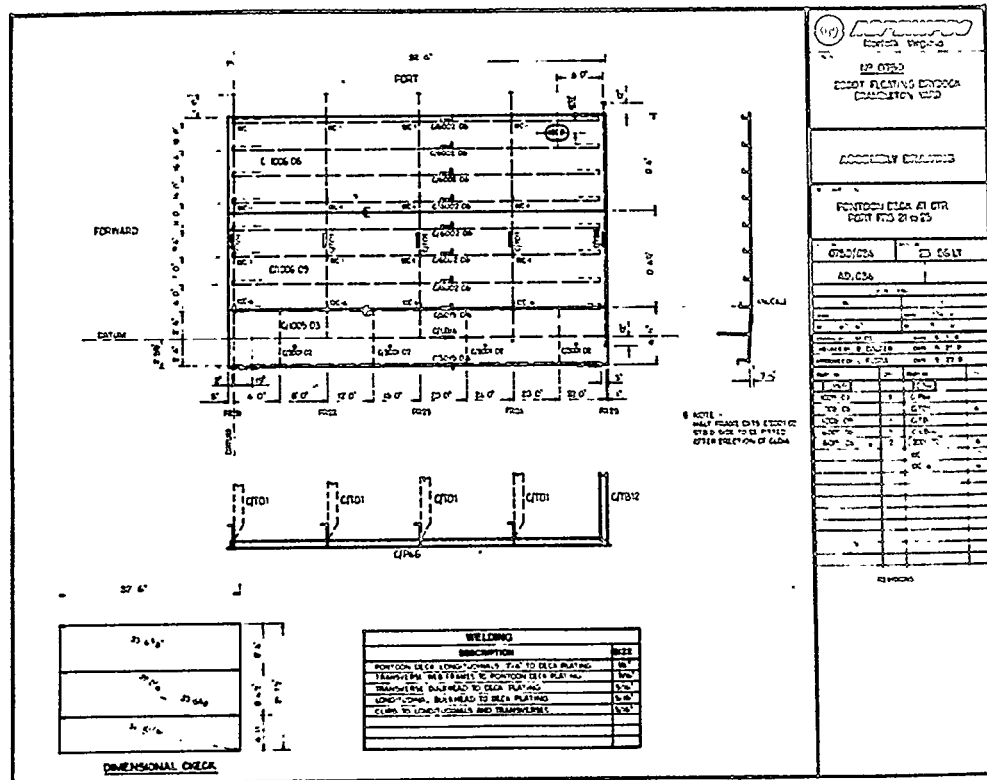
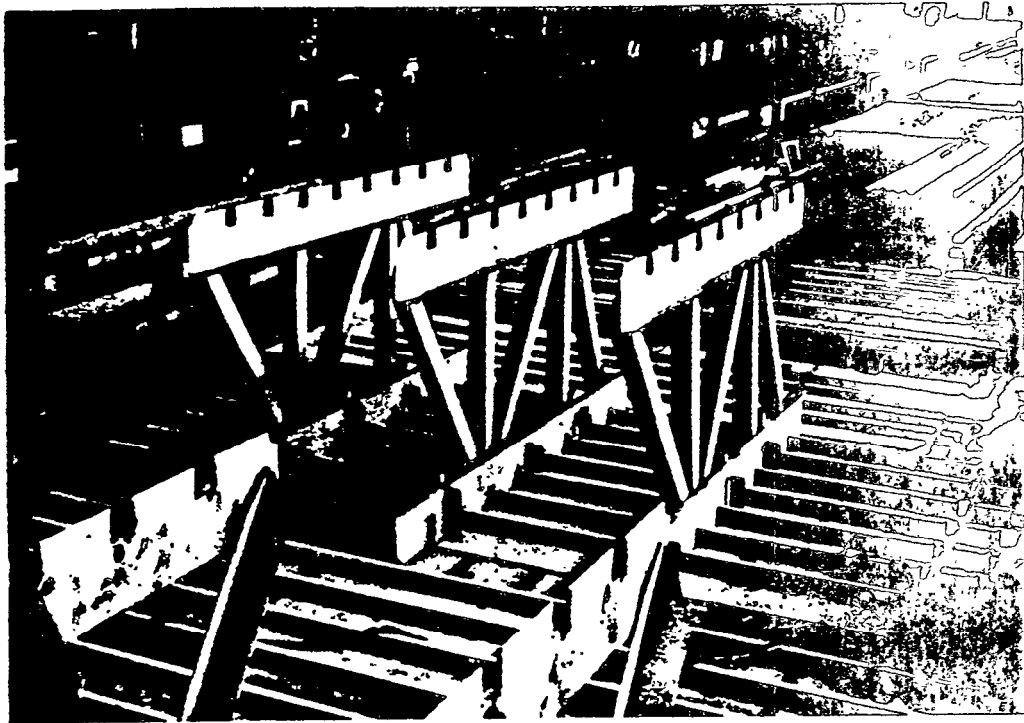




NEW BERTH ERECTION  
SEQUENCE

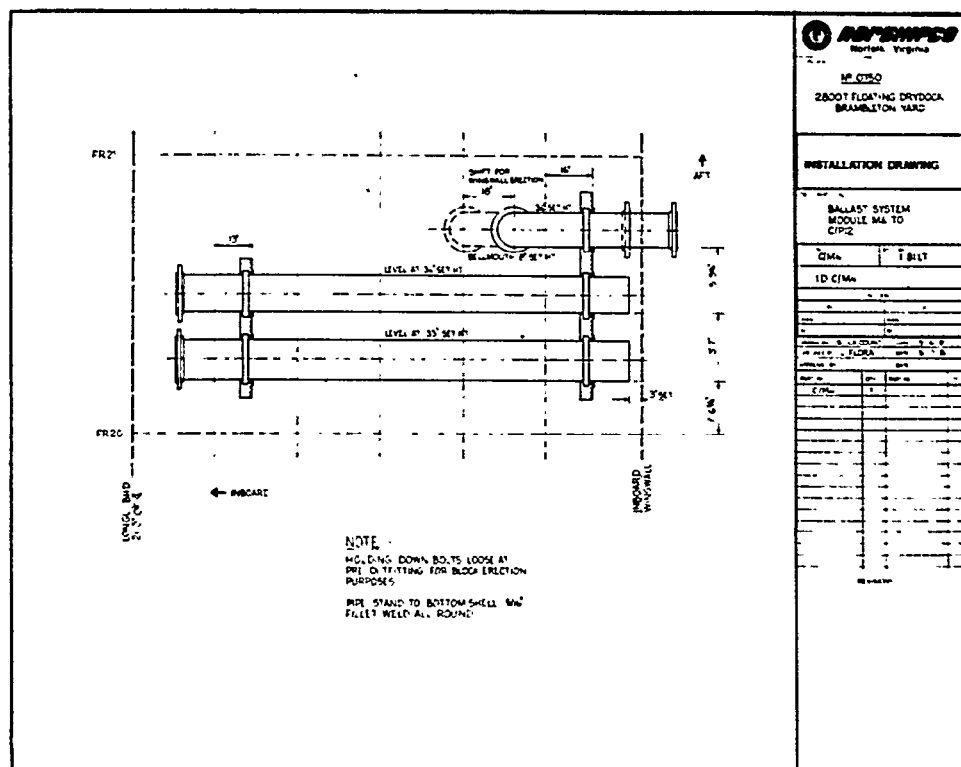
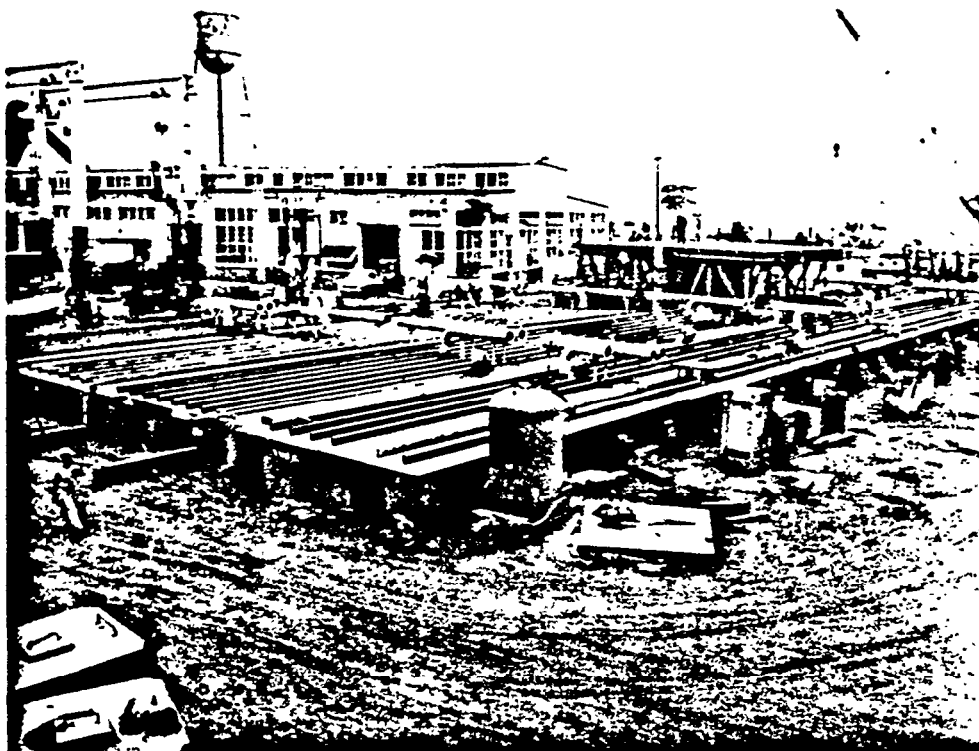
FIGURE 6





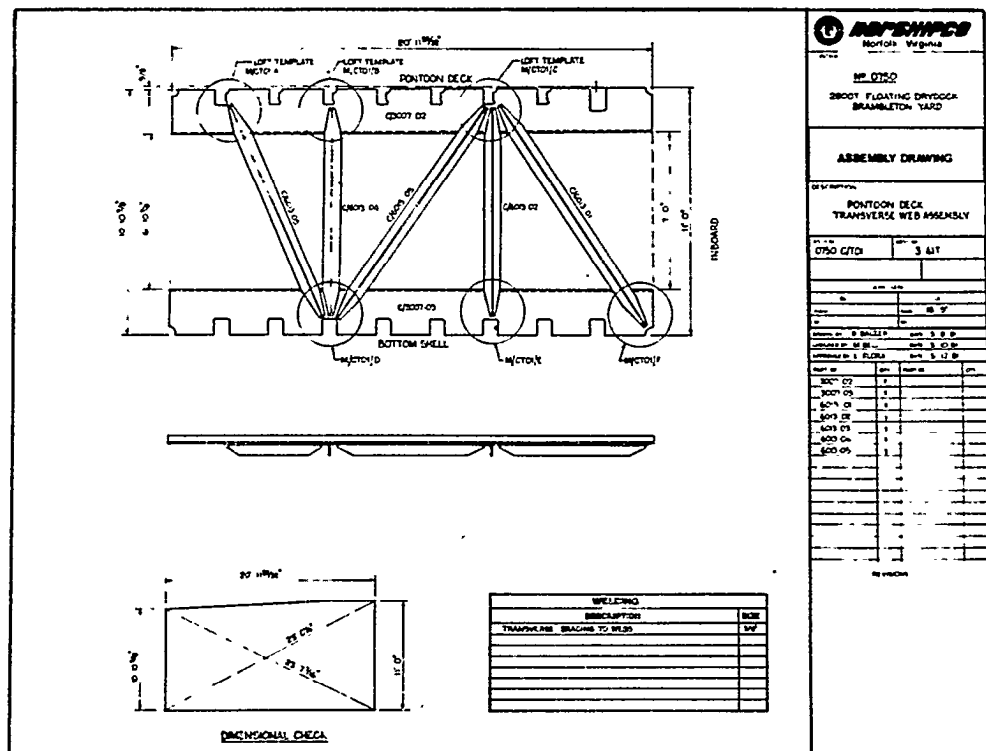
**PANEL AND BLOCK ASSEMBLY  
STAGE DRAWING**

**FIGURE 9**



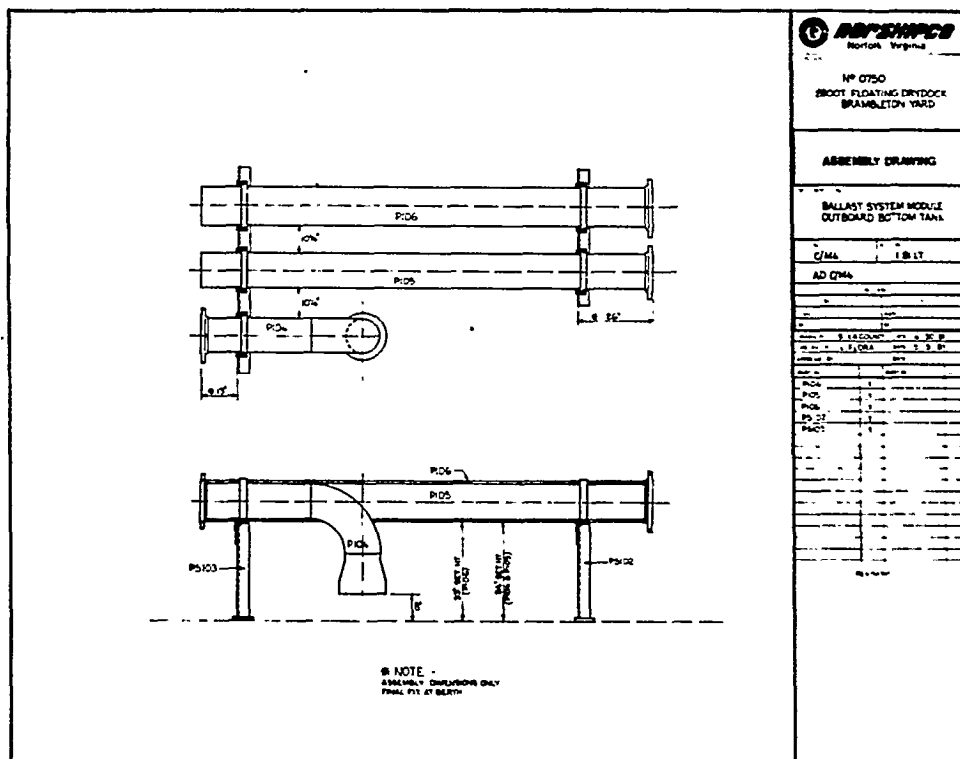
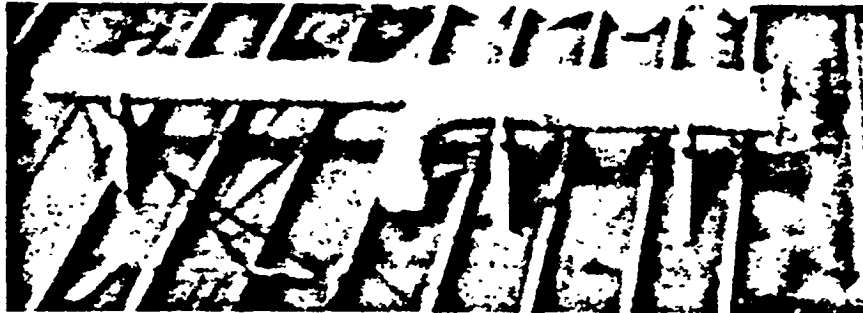
# PIPE MODULE INSTALLATION DRAWING

FIGURE 10



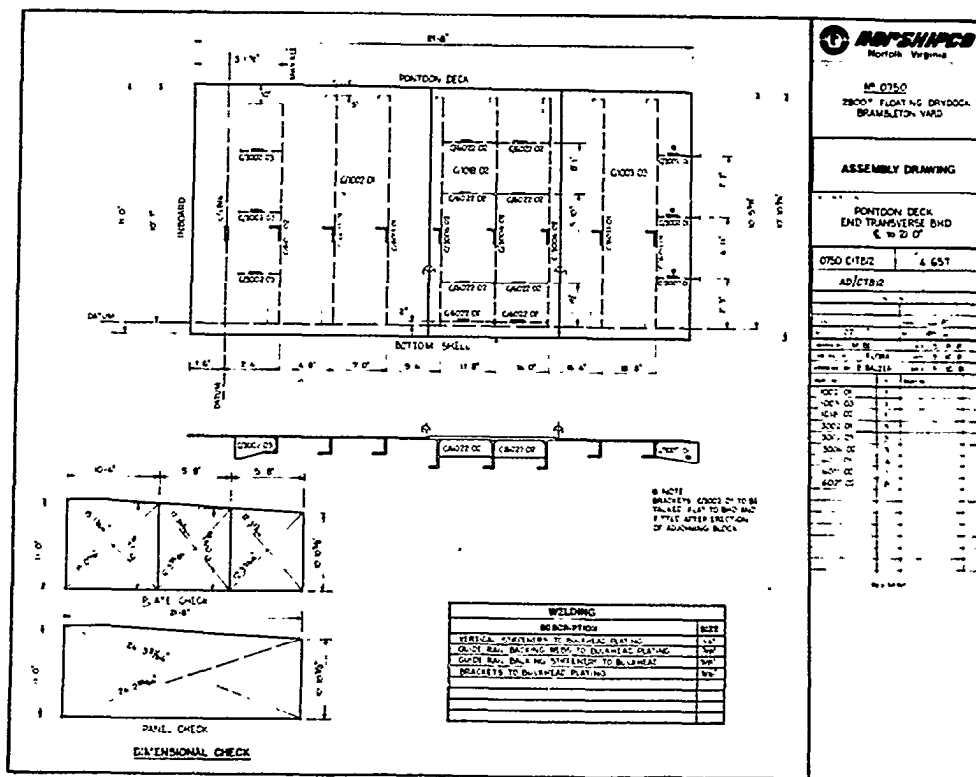
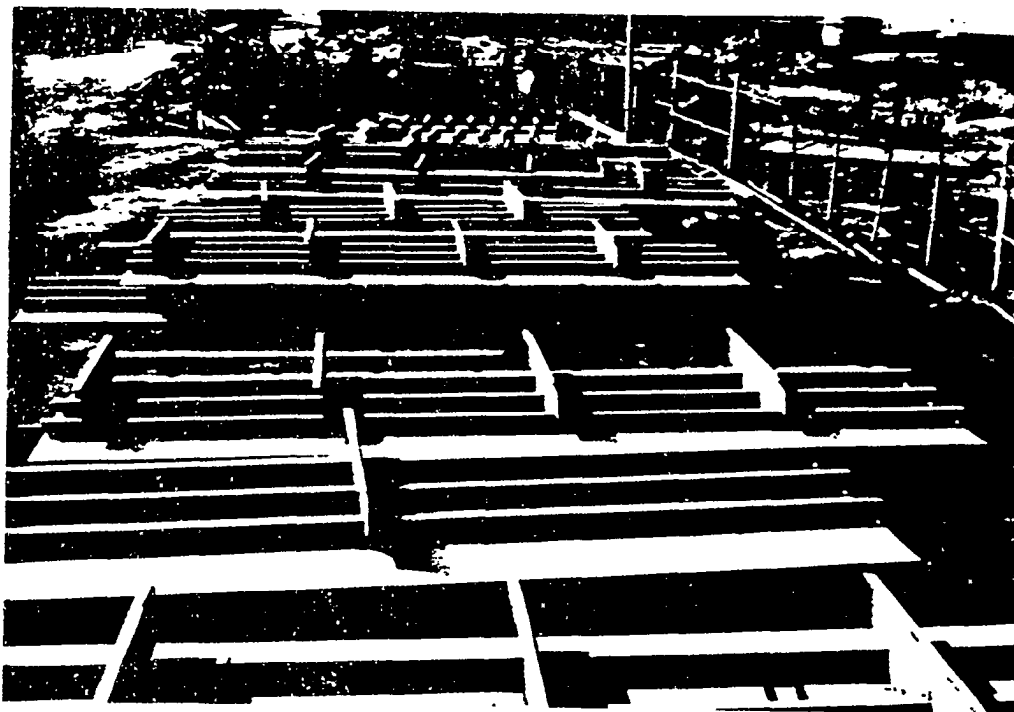
TRANSVERSE WEB ASSEMBLY DRAWING

FIGURE 11



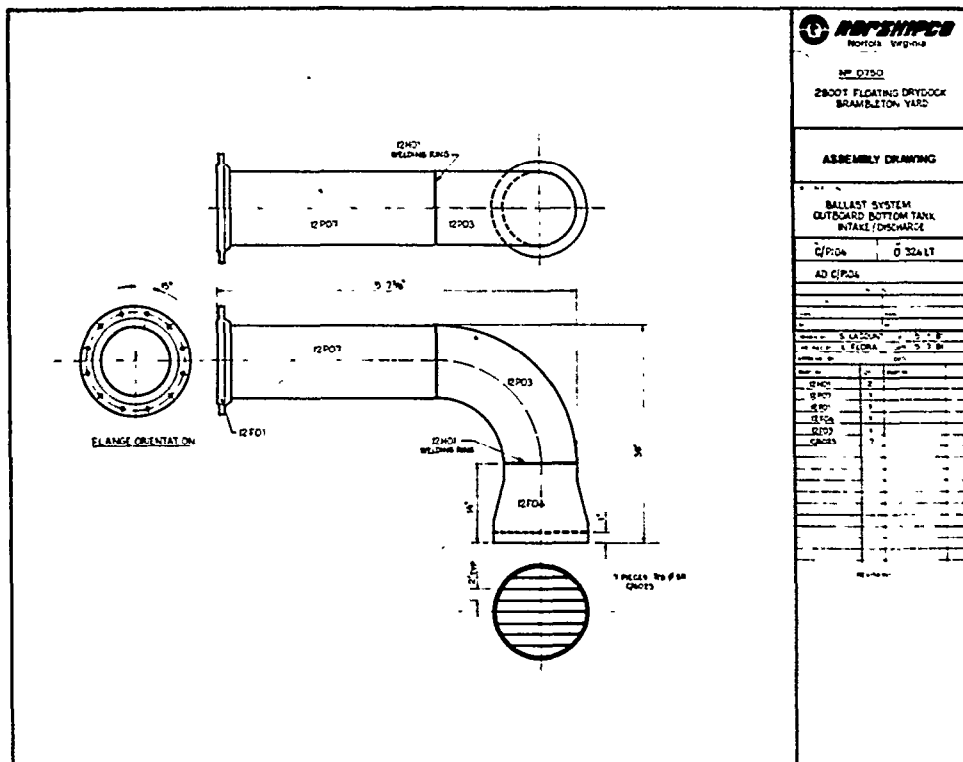
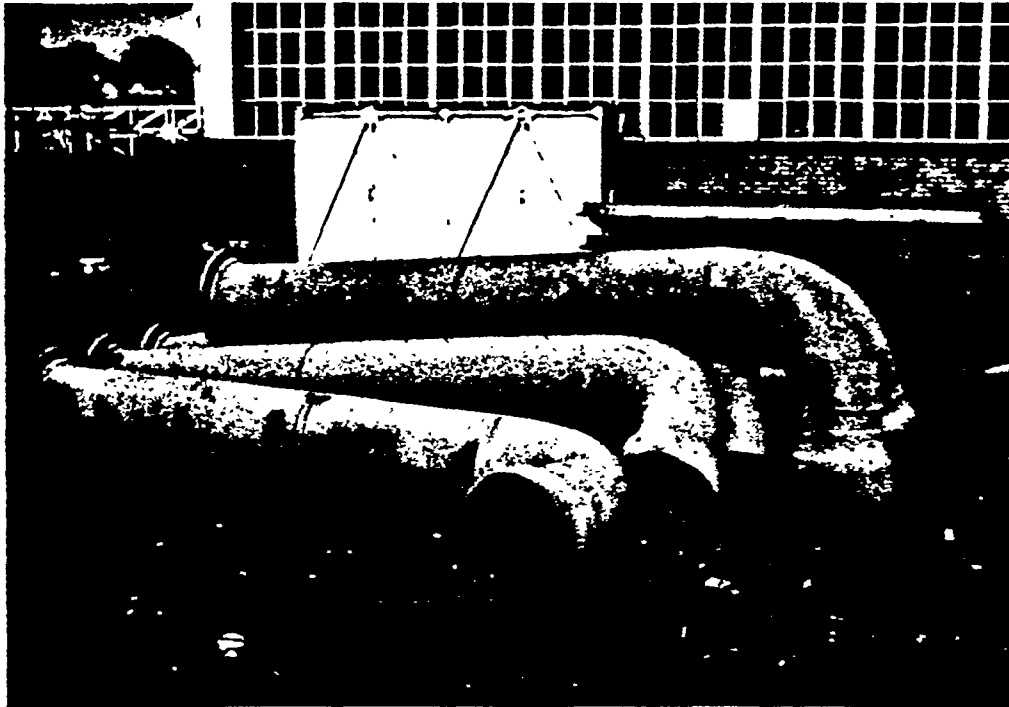
PIPE MODULE ASSEMBLY DRAWING

FIGURE 12



**TRANSVERSE BULKHEAD ASSEMBLY DRAWING**

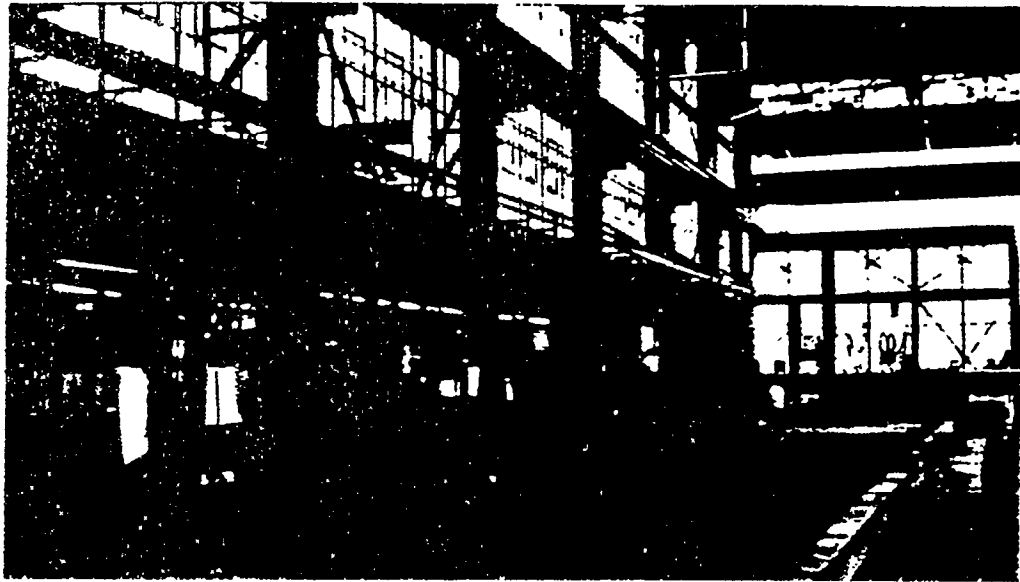
**FIGURE 13**




PIPE ASSEMBLY DRAWING

FIGURE 14





	<b>PLATE CUTTING CM-80</b>	Contract <b>0750</b>	Start Date <b>F</b>
		Prepared By <b>Y. B. MILLER</b>	Date <b>5-8-81</b>
		Revision	Date

#### Plate Material Information

Plate Mark	Qty	Spec	Qty	Spec	Plate Part Created
0750 F 3003	19	F 3003	152		7

#### Raw Plate

Mat. Mark	Length	Width	Height
3003	266	113	15.3

#### Used Plate

Length	Width	Height	Weight

#### Start/Finish relative to Datum Reference

Start	Finish	Start	Finish
1/2"	1/2"		

#### Cutting Information

Location	Part	Sheet	Time
Marking			
Cutting			
Preheat			
Grinding			
Undercut			
TOTAL OPERATION TIME			

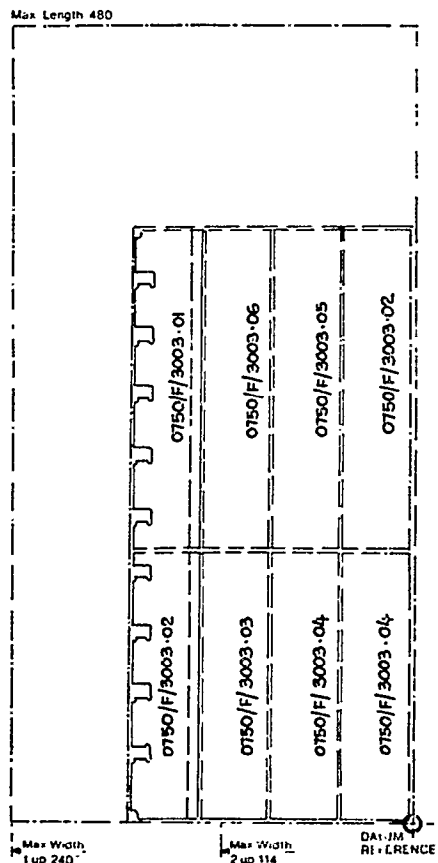
#### Square Cut Plate

Length	Width	Height	Weight

#### Plate Arrangement & Cutting torch Allocation

Bevel Head	
No. 1 Slave	
Bevel Head	
No. 2 Slave	
Master Head	

Operating		Master	
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CUTTING ARRANGEMENT  $\frac{3}{16}'' = 1'-0''$

**FIGURE 15** **PIECE PART INFORMATION**

A MANAGEMENT SIMULATOR FOR SHOP STORES  
IN THE U. S. NAVAL SHIPYARDS

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Los Angeles, California

ABSTRACT

In each of the eight Naval shipyards the pattern of inventory referred to as shop stores contains between 15,000 and 40,000 stock keeping units with a combined value of between \$9 and \$20 million. In general, an item is carried in shop stores if some use for it is foreseen but the use cannot be tied to particular industrial projects. The makeup of shop stores is complicated by the nature of the financing and planning activities in the Naval shipyards.

For several years shop stores has been served by a package of computer programs with many sophisticated options. Among these options are management control parameters for changing reorder points and order quantities on a global basis. The parameters had not been widely used until a pair of simulator programs gave inventory managers a means to link values of the control parameters with measures of performance.

The first simulator looks at individual shop store items and allows them to be classified. Some items may not be appropriate for forecasting techniques, some may benefit from hand set reorder points and order quantities and others may best be given totally to computerized rules. The second simulator considers the totally computerized items and enables management to make the chosen tradeoffs in performance for these items as a group.

For the past four years I and others at California State University, Los Angeles have taken part in training programs aimed at improving the use of automatic inventory control techniques in the U. S. Naval shipyards. The underlying objective has always been better inventory management.. Our focus has been on people who set policy and evaluate results. New tools for getting information to these people have been designed as part of the training programs. The emphasis, however, has always been on effective use of automated procedures that were already available.

The Cal State Los Angeles Training program has been supported by the Naval Sea Systems Command (NAVSEA) under the direction of its Management Systems Support Division (MSSD). NAVSEA has responsibility for construction, modification and maintenance of naval ships. MSSD oversees a number of activities including training and improvements related to the management, information system (MIS) in the naval shipyards. The eight naval shipyards are located in Portsmouth (New Hampshire), Philadelphia, Norfolk, Charleston, Bremerton (Washington), Mat-e Island (California), Long Beach (California) and Pearl Harbour. Almost all of our training program has been conducted at the shipyard sites.

The material used in the naval shipyards is divided into major groups for management purposes. Two of these groups are direct material and shop stores. (Nuclear material will not be considered here.) Direct material consists of items carried to support specific production orders as written on Job Material Lists by the production planners. The Job Material Lists function as a partial Material Requirements Planning system (MRP). Shop stores exist to provide material which either is not identified or cannot be identified with specific jobs, particularly general usage items such as hardware, lumber, metals and so on.

There is great variety within shop stores itself. There are stock items used continually such as work gloves during production, and nuts and bolts which are physically added to the final product. There are also insurance items, such as spare crane parts. Items also vary by source of supply. There is standard material from the Naval supply system, and there are custom orders placed directly with vendors.

### Automation of Naval Shipyard Inventories

During the 1960s a design for an integrated management information system (MIS) was laid out for the Naval shipyards. The modules of MIS, for payroll, job costing and so on, were adopted in the different shipyards over a period of years. By the early 1970s all eight shipyards had installed the MIS module for shop stores. This module remains in place with few modifications. It can perform a number of different tasks with an enormous number of options. The complexity of the shop stores package has led to both misuse and disuse.

In 1977, requests from the ship yards for explanations of the shop stores package lead to the first of several training contracts with Cal State University Los Angeles. In 1979 a group of summary reports called the shop stores Analyzer was added to the main package, and a prototype Simulator to answer what-if questions was constructed. The logic and the computer programs for both the Analyzer and the Simulator were developed at Cal State. Simulator hardware and updated software for simulating performance of single stock items were actually delivered to the Naval shipyards in late spring 1981 during special two day training programs.

### The MIS Shop Stores Package

The need for the shop stores Analyzer and Simulator and related training grew out of the design features of the original MIS shop stores package. The four basic features are:

- 1) Automated perpetual inventory records. This is a daily batch system for posting receipts, issues and orders.
- 2) Automated order writing. This is based on a reorder point and target order quantity for each stock item. Order writing is part of the daily batch run.
- 3) Statistics for each of the 15,000 to 40,000 stock items in shop stores. The statistics include physical usage, variability of usage, frequency of separate issues and leadtime.
- 4) Automatic review of reorder points and target order quantities. The review is done monthly based on the statistics of each item and a set of numeric control factors to be determined by the human manager.

In concept the original shop stores package incorporates most of modern theory for inventory automation. The working environment of the shipyards has been slow to digest and assimilate the theory.

There have been major problems with both input and output. Seemingly straight forward matters such as accurate and timely transfer of receipts and issues to data processing continue to require a great deal of clerical manpower. Perceived information needs have led to locally designed reports in many of the yards. The most critical problem has been lack of direction for the automatic features that are part of the shop stores system. The numeric control factors that govern the system were until recently an unused mystery.

There are five types of control factors available to the inventory manager. There is an order quantity factor which is related to the relative cost of processing orders for new stock versus the cost of holding stock on hand. This factor goes into an economic order quantity formula during the monthly review of stock items. Next come factors which set a minimum and maximum for target order quantities expressed in terms of so many months supply. These are the only factors whose numeric values have a meaning apart from the formulas they enter into. There is a risk factor which influences safety stock. Finally there is a leadtime factor.

Interaction between the control factors complicates their use. Some simplifications were uncovered by research into actual conditions in shop stores. For example, it turns out that any result accomplished by changing the leadtime factor can be gained more efficiently by other means. This means that the leadtime factors can be set to a nominal value and then ignored.

The action of the several control factors is further complicated by the existing shop stores classification system which includes Accounts (Active, Pre-expended Bin, Insurance, and others), Categories (something like the traditional A, B, C inventories) and Federal Supply Classes. Different classifications activate different combinations of control factors. In retrospect, the classification system was made too elaborate for conscientious control. In part, this was an attempt to incorporate all of the existing manual and computer systems for inventory.

The personnel structure of the supply departments in the Naval shipyards imposes limits on detailed experience. The Navy personnel are officers from the Supply Corps. They are skilled in general inventory management and have a good grasp of quantitative and computer methods. Yet they serve limited tours of duty in the Shipyard. Most of the civilian office personnel are clerks with on the job training. There are some very capable oldtimers, but few of these have authority or incentive to change the daily routine.

#### A Program for Managing Shop Stores

Meaningful changes must relate to accepted objectives. Defining a set of objectives which operating personnel will accept as their own should be the introduction to any new procedure. The objectives should be stated in general terms and in terms of specific measurements which will later be used for judging success. People will use new procedures when they see in them methods to achieve the objectives.

The general objectives of inventory management are good service, minimal workload and minimal investment. It is recognized that a balance must be struck between these three objectives; the balance should be a management decision at each point in time. The training program for the shop stores Simulator has presented these objectives in terms of a small number of measurements. The primary measurement for service is the hit ratio, which is the fraction of requests from production which can be filled immediately. The main measurement for workload is the number of separate orders for new stock made each year. Investment is measured by average dollar investment and by annual turnover.

The Analyzer-Simulator link between the original MIS shop stores package and the objectives comes in three parts. Current condition of the inventory is highlighted by the Analyzer reports with respect to demand, ordering, investment and inventory classification. The shop stores Simulator is the device for showing how the automatic features of the original package are governed by the numeric control factors. In other words, the Simulator shows how to go from current condition to the objectives. The third part of the link is the training program itself.

The complexity of the formulas in the shop stores MIS package dictated some form of computerized simulator. For example, the formula used in the monthly review of the reorder point for a stock item is

$$ROP = 1tf * ltd + Z C. 006 * rf * EOQ * UP / FREQ] * 1. 25 * LTMAD / 30$$

where, in particular, 1tf is a leadtime factor, rf is a risk factor and EOQ depends on three other control factors. The other ground rules for



the . Simulator included ease of use by supply personnel, minim21 impact on the main shipyard computer and low cost..

The Simulator developed along the lines of training to prepare the user environment, software and hardware. The training, which is ongoing, concentrates on inventory objectives and the tools available for achieving the objectives. The Software split. logically into a global simulator and a single item simulator. The global simulator estimates the overall impact of changes in the control factors for the inventory as described by current statistics. The global simulator is referred to as the central sector simulator since it excludes stock items whose extreme behavior makes them unsuitable for full automatic management. The single item simulator is used for quick testing of new management ideas and, more routinely, for systematically classifying items. Orderly classification is necessary for control.

From the User's point of View the single item simulator includes a keyboard for data entry and a video Screen. The display on the screen alternates between three electronic pages. Two of the pages are for input, one page for stock item characteristics and one for values of the control factors. The third page summarizes the input and shows the estimated measurements of success with respect to the inventory objectives. The displays are Coupled with prompting messages to the user and online editing of all input amounts.

The electronic input page for stock item characteristics looks approximately as follows.

MONTHLY DEMAND IN UNITS-----?  
VARIATION IN DEMAND (MAD)----?  
AVERAGE ISSUES PER MONTH-----?  
LEADTIME IN DAYS-----?  
SHOP STORES UNIT PRICE-----?

A cursor prompts entries for each characteristic and changes may be made selectively. The second page looks like

ORDER QUANTITY FACTOR-----?  
MIN MONTHS SUPPLY FOR ORDERING--?  
MAX MONTHS SUPPLY FOR ORDERING--?  
RISK FACTOR FOR SAFETY STOCK----?  
LEAD TIME FACTOR-----?

Once the two input pages are filled and edited the simulator calculates for about one second and then displays the output. page. The main part of the output page looks like

hit ratio. . . . . 96. 3%	shorts/year. . 1. 44
average order \$375.00	orders/year. . 8. 00
turns/year.. . . . 9. 14	investment. \$316. 00

The three lines correspond to the three inventory objectives of service, workload and investment.

The hardware for the Simulator was originally conceived as a custom built microprocessor with software in read only memory (ROM). In 1978 the estimated cost was \$45,000 for 9 copies of the device. As delivered in 1981 the simulator hardware is an off the shelf microcomputer with software on diskette at a total cost of \$20,000 for 9 copies. The lower cost shows the benefit of advancing technology. The equipment is also widely available, easy to maintain and versatile. These are qualities one would like to see in any inventory item.

Delivery and the initial training for the single item Simulator took place in May, 1981 for the east coast shipyards and in June, 1981 for the west coast shipyards. Conversations with the yards during July and August indicated the simulator was quickly put to use.

#### A Perspective on Automation

The benefits of the single item Simulator lie in a clear definition of objectives, its discipline for reviewing stock items and the link it provides between control and inventory performance. The progression from the original shop stores computer package to the Simulator is a reminder of how automation should be viewed. Objectives must be straightforward, measurable and will known. People must know how to use and control the automation available to them.

U. S. NAVY CAD/CAM PROGRAM HULL STRUCTURE (HULSTRX)

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ABSTRACT

This paper is a status report on the development of HULSTRX and its integration into the Navy CAD/CAM Program; it presents the implementation of the system outlined by S. Klomparens at the 1979 meeting of REAPS.

The HULSTRX Program effort is aimed at the development of a ship data base containing the locations and scantlings of all hull structural members based upon an established description of the internal and external hull geometry. The data base to be generated will be used for three purposes: (a) development of structural contract design guidance drawings; (b) dissemination of pertinent structural information to other areas of ship design such as arrangement developments, weight estimation and distributive systems backgrounds and composites; and (c) as an aid for the development of structural details, fabrication drawings, and generation of N/C data.

## INTRODUCTION

This paper is an update on the development of the computer program Hull Structure (HULSTRX). HULSTRX is a computer aided design tool for representing and displaying ship structure. When complete, it will be used for both surface and submarine structure. It is being developed for the Navy's Surface Ship Structures Branch as part of the Navy's Computer Supported Design (CSD) Project.

The Navy has recently changed the management of Computer Aided Ship Design and Construction (CASDAC). The early stage or in-house design support will be directed from NAVSEA 03R under the Computer Supported Design (CSD) Project. CSD will be responsible for the development of computer aids used in the design of Naval ships. The intent is to develop an integrated system from early stage design through feasibility, preliminary and contract design. Ship Technical Programs will be managed from NAVSEA 90M and will be supported using Manufacturing Technology funding.

Two (2) years ago, Mr. Stephen Klomprens presented a paper at a REAPS Technical Symposium entitled "HULSTRX-A CASDAC Computer Aid for Hull Structural Contract Design." In this paper, Mr. Klomprens outlined the framework for the computer program HULSTRX and described the objectives for which the program was being developed. This paper is an update of the continuing efforts to develop the program, HULSTRX.

It is the objective of this paper to:

- Review the desired capabilities for HULSTRX within the Navy's CSD system;
- Demonstrate the capabilities which the program presently affords the structural designer; and finally,
- To discuss the ongoing and future development of the program.

## BACKGROUND: THE NAVY CSD SYSTEM

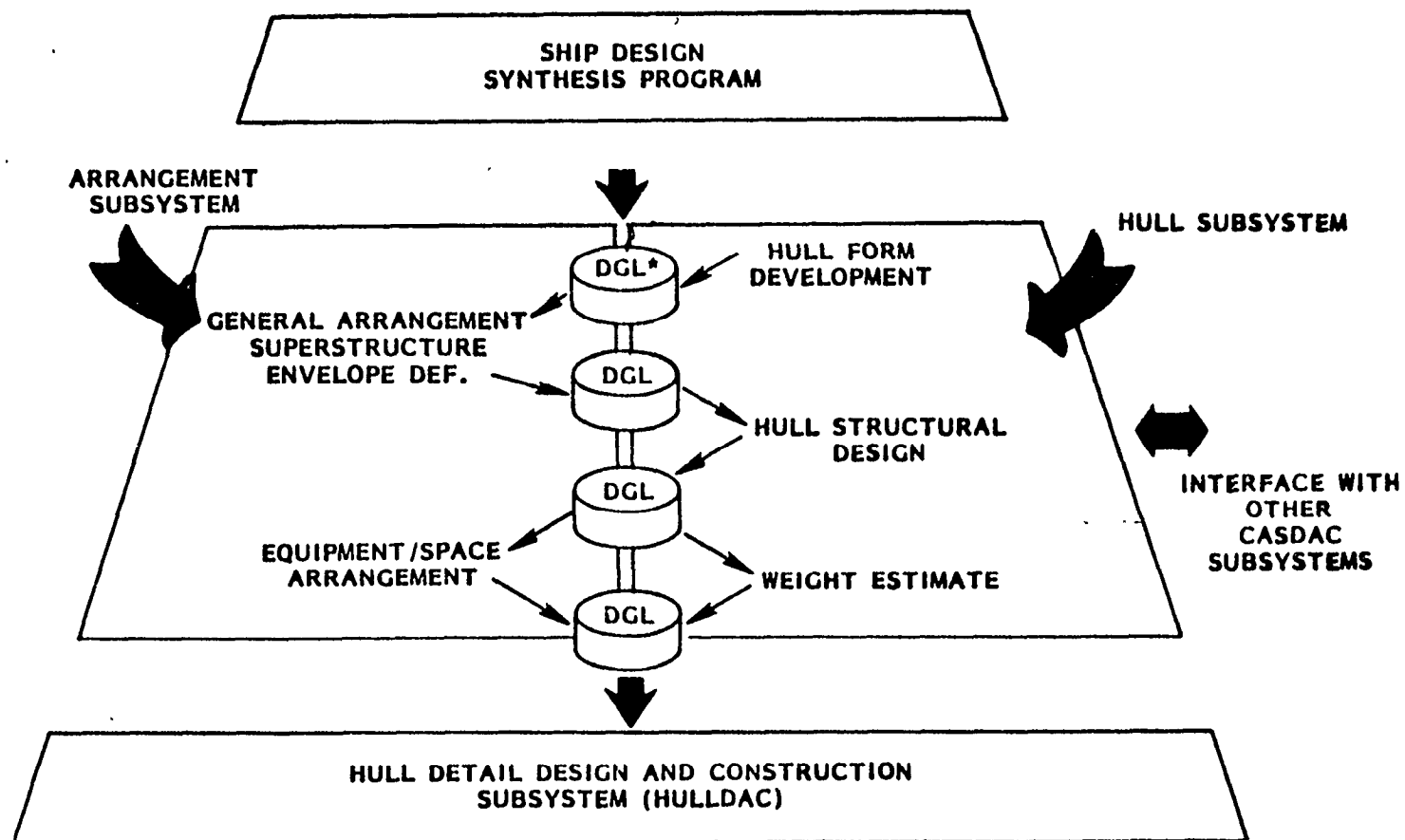
The Navy's CSD project is an effort to develop and use computer generated data to support the design community. It is a combination of several computer design tools which access a set of common data bases during the ship design process. To insure that designers involved in one facet of the design process coordinate their efforts with other design efforts, the concept of the Design Geometry Library (DGL) was established.

Essentially, the DGL represents the description of the ship design at any given time and is subdivided into the principal design areas of hull form, arrangements, and structures. Figure 1 depicts the Navy's CSD system and the role of the DGL. The importance of the DGL to this discussion is that the DGL serves as the primary interface between the structural design programs and the other computer programs used in designing a ship.

Figure 1 also demonstrates the role of HULSTRX within the Navy system. The hull form portion of the DGL contains a description of the hull form and is created primarily by the program HULDEF.\* The arrangements portion of the DGL, created by DEKOUT\*, contains the locations and descriptions of decks, bulkheads, and major openings. HULSTRX draws upon data within these two data bases and creates the structural portion of the DGL. The structural portion of the DGL contains the location and description of structural members which lie on the hull form, decks, bulkheads, and other surfaces. This portion of the DGL can then be used in many ways:

- As input for other structural design programs;
- As a basis for computer generated structural drawings;
- As a design deliverable in and of itself.

\* For convenience, Appendix A provides brief descriptions of Computer programs which develop the DGL or use the DGL as input for calculating their specific output.



\*DGL: DESIGN GEOMETRY LIBRARY

Figure 1 - The Navy CSD System

HULSTRX has been subdivided into two parts for effective development. The first stage of the program has been directed toward defining the traces of structural members on the surface in question (e.g. deck, bulkhead, or shell). The second stage is intended to define the scantlings of each specific member (i.e., properties such as web depth, flange width, thickness, orientation to the molded surface, materials, etc.). The portion of the DGL currently developed is the structural trace file. The second stage of HULSTRX development will incorporate the structural scantling information. This paper will not address the development of that portion of HULSTRX which creates the scantlings file as this effort is being performed separately.

#### HULSTRX OBJECTIVES

At the conception of HULSTRX, the design deliverables to be addressed included:

1. Drawings of midship section and typical sections;
2. Deck drawings for all decks;
3. Shell expansion drawings;
4. Deckhouse or superstructure drawings;
5. Longitudinal strength study;
6. Other structural calculations.

As HULSTRX has developed, the emphasis has been redirected towards establishing the structural portion of the DGL and thus allowing the development of structural drawings. Calculations have been left to other structural design programs, such as the Structural Synthesis Design Program, SSDP. Essentially, the current objectives of HULSTRX can be summarized as follows:

1. Develop shell expansion drawings showing all structural traces, bulkheads, decks, and plating;
2. Develop deck drawings showing structural members for all decks, including superstructure and associated surfaces;



3. Develop bulkhead drawings showing structural members for all bulkheads, including superstructure and associated surfaces;
4. Develop midship and typical section drawings showing hull plating, shell stiffeners, bulkheads, decks, and associated surfaces;
5. Provide a complete data base of the structural Contract Design.

In its present form HULSTRX is operational and can meet the first three objectives. With initial input of the hull form and arrangements portions of the DGL, HULSTRX can be used by the designer to locate stiffeners and arrange plating. In batch mode, an expanded shell drawing can be developed by HULSTRX and plotted by UPLLOT (a utility drafting routine). Similarly, bulkheads and decks defined in the DGL can be complemented with structural members and plating boundaries: using UPLLOT, bulkhead and deck drawings can be produced. HULSTRX requires further development to satisfactorily develop sections: while the shell boundary can be determined, the stiffeners on the shell are not readily shown. This limitation will be bypassed with development of the second portion of HULSTRX allowing the definition of the scantlings file.

Figures 2 through 4 show examples of drawings developed using HULSTRX generated structural traces. Examination of these drawings will clearly show HULSTRX's present capabilities and also its limitations. Later, we will examine the internal mechanics of HULSTRX and identify the causes of the program exigencies.

Figure 2 is a shell expansion for a typical destroyer hull form. Note the clear presentation and the line quality. In order to generate this drawing, the operator, in a batch mode, used the hull form description and the location of decks and bulkheads contained in the DGL as input and added the structural traces. The traces are input as two dimensional traces that are converted into three dimensional traces which lie on the shell surface.

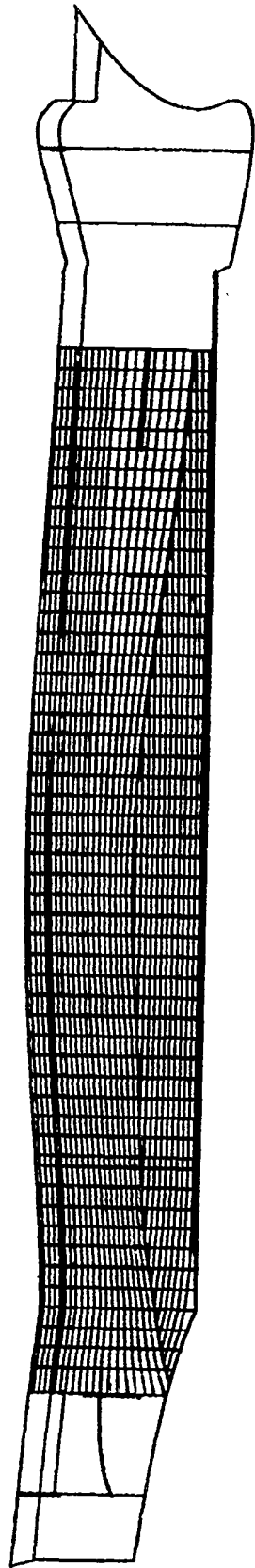


FIGURE 2. SHELL EXPANSION

Alternatively, the designer can select two existing lines, surfaces, or structural traces and input a desired number of equally spaced traces; HULSTRX would then determine three dimensional traces with the desired spacing (the equal spacing can be in terms of girth or one of the coordinate directions.). After any specific run, the designer can choose to plot the shell expansion to graphically inspect his work.

Figure 2 contains an example of one of the programs' limitations; HULSTRX is not capable at present to depict a satisfactory shell expansion of a ship which has a bulbous bow or other appendage. The shell expansion is distorted in way of skegs and bulbs because of the extra girth added by the appendage. The extra girth created a bulge in an ostensibly straight stiffener. In manual practice, the bulb and skeg are simply "tacked on" the bottom of the shell expansion. An appropriate method of handling these discontinuities is under study.

Figure 3 is an example of a deck drawing . Deck drawings can be very satisfactorily developed using HULSTRX and UPLLOT as this drawing shows. At present, the drawing lacks stiffeners which intersect the deck perpendicularly; frames are not shown where they meet the deck, nor are bulkhead stiffeners. In the case of deck drawings, this is not a significant problem as such information represents only a small portion of the drawing. It becomes a more significant problem when portraying bulkheads and sections as later figures will show.

Figure 4 is a typical bulkhead developed by HULSTRX and UPLLOT. The complexity is similar to that of the deck plan and, as stated above, the absence of perpendicular members is more apparent. A resolution for this limitation is under development.

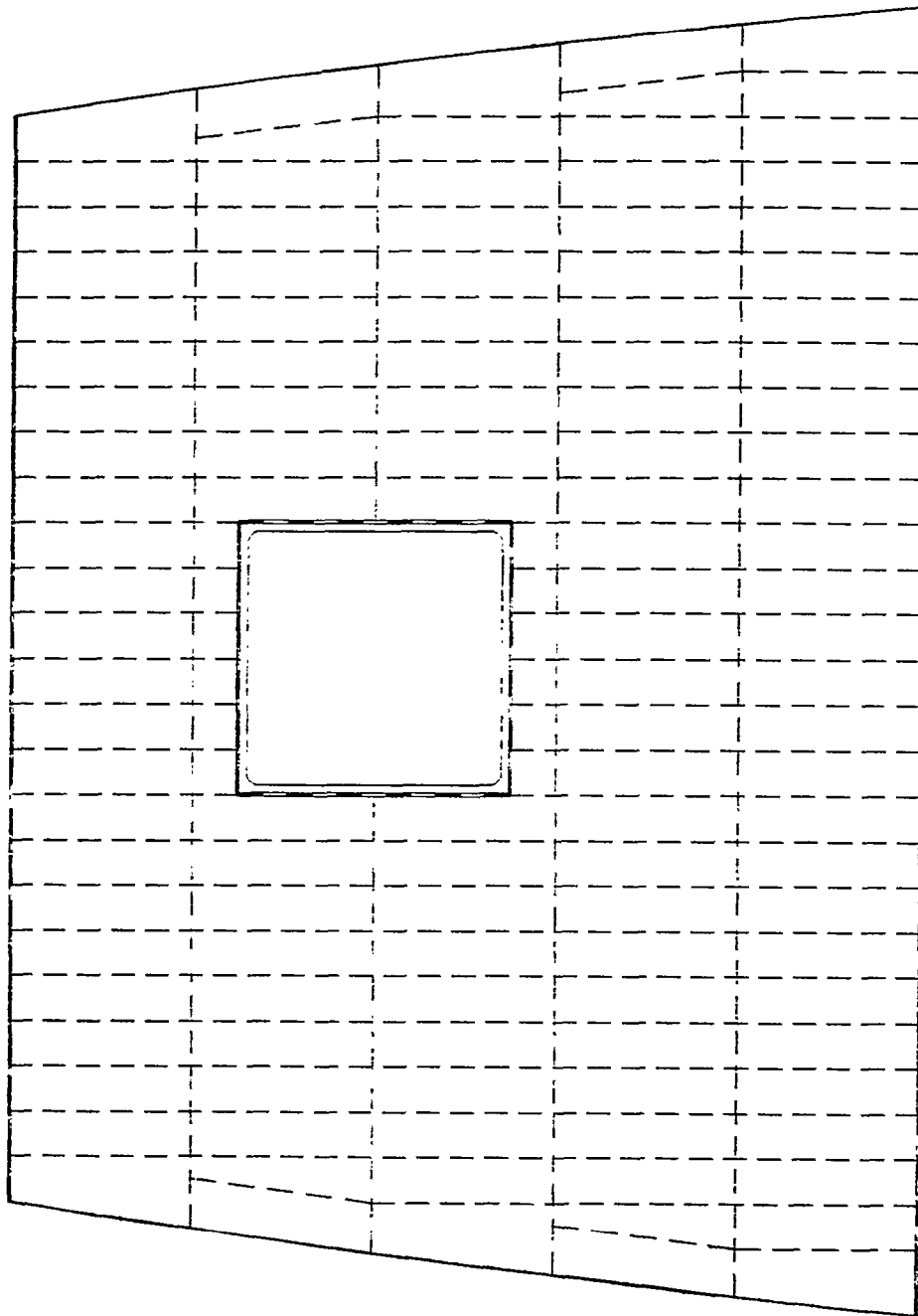


Figure 3 - Deck with Stiffeners

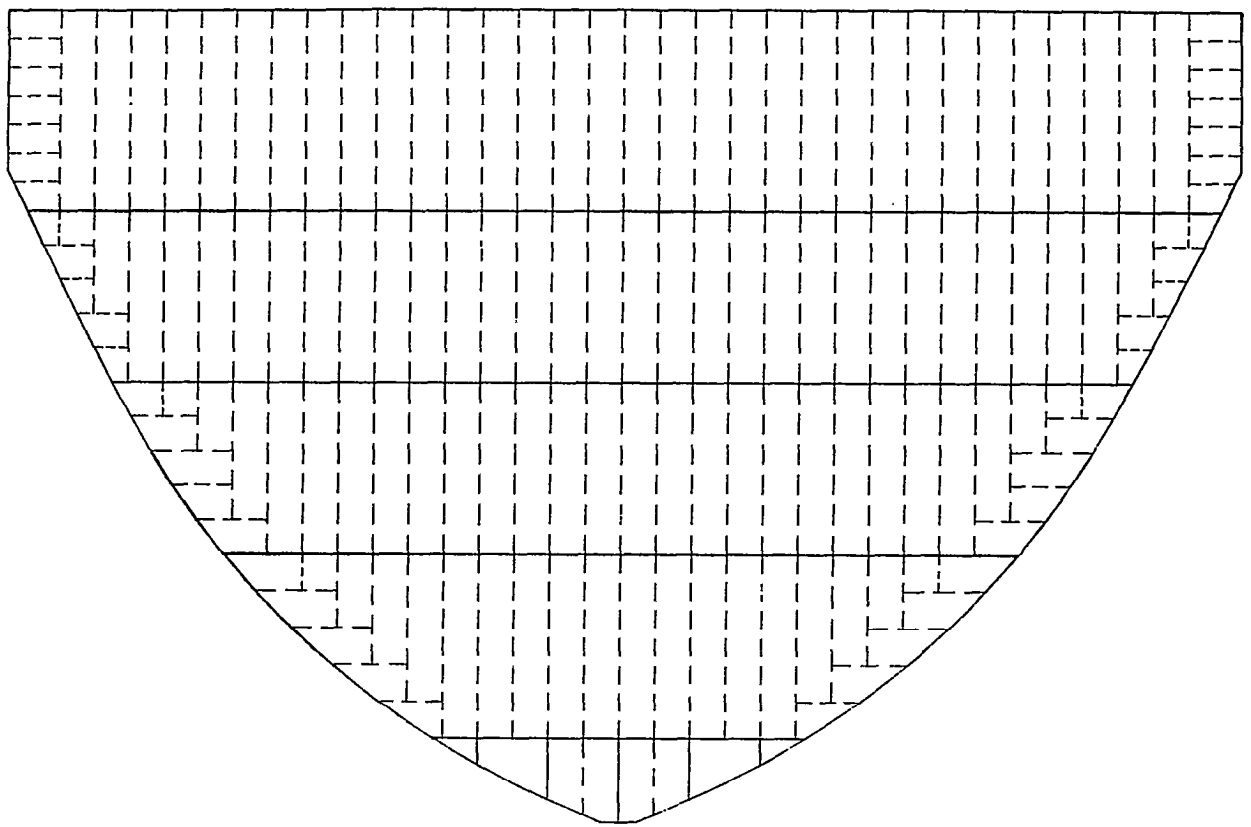


Figure 4 - Transverse Bulkhead

## OPERATIONAL ASPECTS

A flow chart showing the operational steps of HULSTRX is shown in Figure 5. Some of this material has been presented in Reference 5. Essentially, the designer begins with a mathematical description of the ships surfaces and a desired scantling configuration. The designer transforms the scantling configuration into input data which are sets of points, or sets of points and tangents. After HULSTRX operates on the input, the designer reviews the output and modifies the input data until he is satisfied with the representations. Several runs may be required to achieve the desired detail; performance should improve with experience.

HULSTRX adds traces of structural members to a working file for each surface during execution. Once all traces are added to a surface, the working file of structural traces for that surface is written to a revised DGL. The revised DGL file contains all the surface definition information of the original multi-surface DGL file plus the new structural traces currently being added to the surfaces being considered. Each batch run must use all current structural traces since old traces are not retained. The original multi-surface DGL file is not modified during execution and may be retained or deleted at the user's option. Only the structural portion of the DGL can be modified by the structural designer using HULSTRX.

HULSTRX performs its manipulatory functions by utilizing a temporary grid file of each surface. This temporary file is searched to determine points of intersection with the specified structural trace. The points of intersection are splined together and then faired to form a line on the surface. This new line is then written to the working surface file. Once all the traces are written for one surface and that surface is complete, the trace file is written to the revised DGL and the grid surface and working file are discarded.

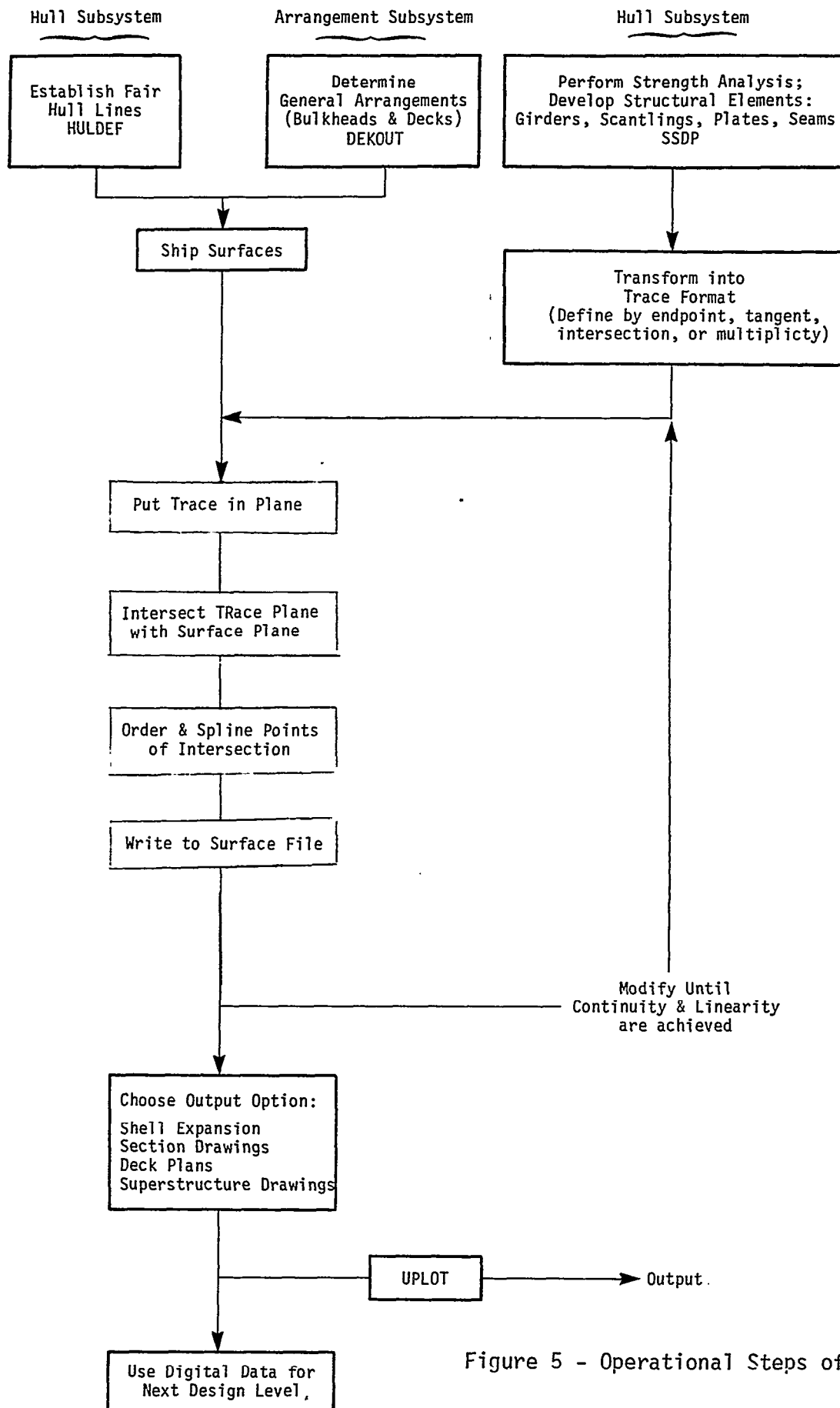


Figure 5 - Operational Steps of HLSTRX

Until a surface is complete, the working file of traces must be kept on hand in case a previously calculated trace is specified as an intersection line.

Details of the current HULSTRX development state are presented below under the categories of :

1. Design Geometry Library (DGL) structure;
2. Structural trace processing (mapping methodology);
3. Inputs to the program; and
4. Outputs from the program.

### Design Geometry Library

The file structure and format of the data base that HULSTRX works with is the same as that used with HULDEF with an additional capability to handle multiple surfaces. The DGL is a sequential access file containing unformatted records. Record length is determined by the input/output (I/O) list in the read or write statement. The first record of the DGL contains the ship identifier, comprised of up to 20-characters (5A4), and the ship creation (or version) date, 8-characters (2A4). The remaining records on the DGL are broken up into surface blocks, as shown in Figure 6. Each surface block contains a 6-character surface identifier (the first record on the surface), followed by all lines on that surface. Lines are described by a 6-character identifier (3A2), line type (an integer), the number of segments in the line (an integer from 1 to 50), then the segments in endpoint/tangent form (SEGS {13,501). (Only the last 12 values of each segment actually are present.) The sentinel for the end of the surface block is a blank line identifier. The sentinel for the end of the DGL is a blank surface identifier.

The naming conventions for the 6-character surface and line (trace) names are presented in Table 1. The names start with a mnemonic string of 2 or 3-characters, and are filled out to 6-characters by the program user



or internally generated by the program. Some of the names may have an implied decimal point location to allow the trace name to contain a numerical position. This information is optional for structural traces and is currently only used by HULDEF. The names assigned to lines are used to define the line type code. Each line type code is drawn with a different kind of line.

SHIP,      DATE	
SH000S    (SHELL STARBOARD) CLO00      CENTERLINE SHELL GEOMETRY LINES BLANK <sup>(1)</sup>	SURFACE NAME TRACES IN END- POINT TANGENT FORM (HULDEF'S FORMAT)
SH00OP    (SHELL PORT) SAME FORMAT AS FOR SHELL STARBOARD BLANK	SURFACE NAME TRACES IN END- POINT TANGENT FORM (HULDEF'S FORMAT)
DECK 1	
DECK    ( 2 )	
PLATFORMS	
FLATS	
TRANSVERSE BULKHEADS	
LONGITUDINAL BULKHEADS	
GIRDERS	

NOTE:

- (1) BLANK TRACE NAME INDICATES END OF SHELL SURFACE
- (2) EACH DECK, OR ANY OTHER CATEGORY OF SURFACE, MAY BE REPRESENTED AS A INDEPENDENT SURFACE SUB-FILE.

FIGURE 6 - DESIGN GEOMETRY LIBRARY DATA REQUIRED AS INPUT TO HULSTRX

TABLE I

<u>SHELL GEOMETRY TRACES</u>	<u>IDENTIFIER</u>
FORM LINE	
GIRTH LINE	GL-----
CONTROL LINE	C-----
DISPLAY LINE	D-----
STATION	STA---
FRAME	...
WATERLINE	WL-----
BUTTOCK	BT-----
DIAGONALS	DI-----
 <u>ARRANGEMENT TRACES</u>	
TRANSVERSE BULKHEAD	TB-----
WEB FRAMES	WF-----
DECK	DK-----
PLATFORMS	PF-----
FLATS	FL-----
LONGITUDINAL BULKHEAD	LB-----
SKEW BULKHEAD	SB-----
JOINER BULKHEAD	JB-----
 <u>STRUCTURAL TRACES</u>	
STIFFENER	ST-----
SEAM	SM-----
BUTT	BU-----
MASTER BUTT	MB-----
HEADERS	HR-----
GIRDER	GR-----
 <u>MISCELLANEOUS STRUCTURAL NAMES</u>	
PLATE	PL-----
PIECE	PC-----
HOLE	HL-----
BREAST HOOK	BH-----
FASHION PLATE	FP-----
INNER BOTTOM	IB-----
SUB-ASSEMBLY	SA-----
CHOCK	CK-----
BRACKET	BK-----
WEB	WE-----
FLANGE	FG-----
ANCHOR RECESS	AN-----
APPENDAGE	AP-----

## Mapping Methodology

Development of HULSTRX included establishing how the structural trace would be accurately mapped onto the various ship surfaces. This mapping process will be described for the shell surface. Before describing the procedure, however, it is first necessary to describe the means for defining the shell geometry.

Surface geometry is defined by a set of grid surface definition lines formed from longitudinal and transverse lines. These lines include a set of control lines which include lines for the centerline, half siding, transom, deck-at-edge, etc. and a group of longitudinal lines. Flat surfaces such as transverse bulkheads, decks, etc., are defined simply by the lines at edges.

For the shell, longitudinal definition lines are primarily iso-girth lines. An iso-girth line is a longitudinal line formed by splining points on sections, where the point on each section is located at a specific fraction of the girth at that section. Additionally, the shell surface geometry can be further defined with other types of longitudinal lines such as waterlines. The longitudinal shell definition lines also include other control lines that specify knuckles or flat plate areas in the hull. For the purposes of this discussion, longitudinal shell definition lines will be referred to as L-lines.

Only the L-lines are used to generate transverse lines (T-lines) which forms the second dimension of the shell definition grid. A T-line is created by intersecting an X-plane with the L-lines. All the points of intersection are splined together to form a line then stored in a working file. The number of transverse cuts of the L-lines made to create this temporary file of T-lines is user-dependent. A T-line is made at every station and in the default case this is automatically supplemented to include T-lines at  $1/4$ ,  $1/2$  and  $3/4$  station spacing.

Together, the L-lines and the T-lines form a grid of lines over the surface which completely defines its shape. The only information needed to generate this grid is the original L-lines and, for the shell, the stations from the HULL DGL. This information, together with the parametric spline and line-cutting algorithms, provides for a concise means of representing a surface.

Once a temporary surface file is established in memory, each structural trace is mapped onto the surface. The mapping of a trace onto a surface consists of placing the trace in a plane, intersecting this plane with the plane of grid lines, finding the points of intersection and ordering and splining those points to form a line. If a line is entirely in an X-plane one processing step is automatically saved by operating on the original L-line file without the T-lines.

The projection plane of a trace is usually obvious to the user and is selected during input operations. The most accurate projection results when the plane is perpendicular to the surface. For instance, longitudinal stiffeners on the shell located toward the bottom should be placed in the Y-plane, while longitudinal stiffeners on the upper shell should be placed in the Z-plane. Improper selection can result in an inaccurate trace, so the user must be cognizant of all input options available and geometry of the working surface.

The endpoints of a line to be projected must fall on T-lines when projected. If the endpoints do not fall on a T-line, additional T-cuts are generated. Four T-lines forward and aft of the line endpoints are also used, if available, to assure an accurate mapping of a line onto the shell. The splined line resulting from the intersection of the trace and the surface is stored on the surface file only between its actual endpoints.

If an error is encountered during the processing, the program usually does not terminate, but rather an error message is written via the line printer and processing for the next trace started. Some errors, however, are fatal, such as not finding a specified surface file.

### Inputs

Three kinds of information are required by HULSTRX as previously shown in Figure 5. They are:

1. Hull form lines
2. Arrangement information, and
3. The structural designer's concept of where the traces should be.

Hull form lines and arrangement information are accessed internally through the DGL. Structural traces require external user inputs.

The basic input to the structural design effort and to HULSTRX is a digital file of the geometrical shape of the hull and the major hull subdivisions as represented by surface intersections. This file was discussed in the DGL section and was shown in Figure 1.

The user input to HULSTRX is a two dimensional description of the desired structural trace and scantling data for the structural member the trace will represent. The structural traces can be input by a variety of methods. The structural trace in endpoint coordinate form can be projected onto the hull from the X, Y or Z planes. In addition, the girth of the structural trace from the ship centerline can be specified at various points and the trace determined from that information. Other input options consist of the ability to create a given number of evenly or equally spaced traces between two specified lines, and the ability to demark a line, by specifying other lines that it is to intersect,

By using the various input methods the designer can achieve a satisfactory definition of the structural traces on various sections of the hull more easily than would be possible using only one method. By using the logical input method for different sections of the shell, satisfactory trace definitions can be achieved more quickly. A good general order for ordering input structural traces is to place the longest structurally continuous piece first. This allows the user to use a line as a trace endpoint instead of relying on (inconsistent) measurements of the endpoint.

The input routines for HULSTRX allow the input to be in a free field form. The inputs are all keyed on a code consisting of a two digit string which always appears in the first two columns. The type of data which will be expected on the following line and also the operation to be performed on the data depends on the contents of that code. Input on the rest of the line is of the free field type. Data and keywords can be separated by commas or blanks or combinations of the two. The input consists of a line name followed by a series of coordinate pairs. These points are used to generate a line in endpoint-tangent form. In addition the end tangents of the line to be generated can be designated during input. For multiple line capability, data includes spacing, number of lines, and boundary lines. Lines of intersection can also be input. A sample data deck is presented as Figure 7. It shows some possible input forms.

#### outputs

Several output files are created by HULSTRX,

1. Revised multi-surface DGL,
2. Shell expansion file, and
3. Multiple lines file.



The revised multi-surface DGL is the main output. From it, a drawing of any surface can be created. The shell expansion file is a job option and can be used to create a shell expansion drawing without further manipulation. The multiple lines file is solely a users' tool. It is used as a starting point to add detail to individual lines created en masse for input into the next HULSTRX cycle.

### DESIGN CONSIDERATIONS

Integration of HULSTRX with the CSD system required design similarity with the Navy programs already developed; therefore, HULSTRX employs many of the concepts implemented in the HULDEF program. The three most important concepts used in parallel with HULDEF are:

1. the file structure and format used for the DGL;
2. the parametric spline used to represent structural traces (3-D lines);
3. the present use of the program in a batch mode.

Many of HULDEF's routines that deal with the lines file and manipulate lines are used in HULSTRX for consistency, and are described in References 3 and 4.

Development of HULSTRX itself has proceeded at two levels: an external user/computer interface, and an internal data manipulation level. The external level tradeoffs include modularity, preprogrammed input decisions and program complexity. The internal tradeoff level concerns the production of the files for the DGL.

### External Consideration

Modularity is required in any good programming effort, if only to clearly present the logical flow of the program. For the CSD system, modularity has extra value since modules which are not program-dependent can be used



in other subsystems. This simplifies the integration of the separate programs into a unified whole. In HULSTRX the use of blank common blocks was held to a minimum to achieve independence. Also, sections which might be useful elsewhere, in this program or another, were separated from their parent sub-routine.

The amount of input processing desirable was a trade-off constrained on one hand by ease of use for the programmer and on the other by program complexity necessary for decoding the input. Since much of the structural data would have to be input manually or adjusted frequently, a versatile input device was desirable. On the other hand, each additional format that had to be decoded or handled specially added to program size and complexity. The input options made available were discussed previously. Other options may be added as user feedback appears. The input format was developed considering that eventually input will come from SSDP.

Program complexity also entered the design stage in the specification of what the program was to handle. Providing for every eventuality would over-complicate the program and lead to an over-sized system. In general, many trade-offs were made. For example, line traces were limited to having at most 51 points in their definition. Ensuring the program could handle all possibilities likely to arise was a large part of the design in order to avoid user restrictions.

#### Internal Consideration

Programming problems on the internal level were not so much trade-offs as they were making the program do what it should do. One exception to this was the handling of input errors. Two extremes for dealing with errors are: operating on the false data, and not operating at all. The median solution for HULSTRX was to have the program throw out the line defined on the incorrect data card and continue processing other lines.

The internal problems that had to be solved to get HULSTRX to run properly were mainly in the shell expansion output option. Difficulties with the program occurred when trying to handle non-continuous features such as bulbs, skegs, tunnels, and the transom. Two types of discrepancies arose in handling non-continuous features. One occurred because of the girth-plane representation of the points on the shell. The shell expansion was distorted where appendages added or subtracted girth from the hull.

Extra girth creates a bulge in an ostensibly straight stiffener. Designers simply tack the skegs on after the shell scantlings are developed and do not look at the girth of the shell. This easy solution is not obvious to the computer which relies on a strict geometrical definition of the hull; an appropriate method to handle this is under development.

A second type of distortion occurred where the slope of a line was discontinuous. These were places such as connections of skegs and sonar domes, junctures of flat sections of the hull with curved sections, and sharp edges like the prow and the transom. For this, a further definition of the demarking lines and boundaries was needed to account for the discontinuity.

A major developmental problem was distinguishing between inaccuracies that arose from incorrect input data (a user problem) and those that arose from program errors. An original data base derived from a combination of structural drawings and an existing HULDEF generated hull form was used to aid in program development. Several inconsistencies discovered in the drawings from which the HULSTRX data was derived were the cause of errors in the HULSTRX output. Other errors were produced by limitations in the HULDEF derived hull form description.

HULDEF utilizes a "wire mesh" definition of a hull form to define the hull surface. This is satisfactory for developing the lines plan which is HULDEF's principal purpose. The designer responsible for the lines plan manipulates his HULDEF input until an acceptable lines plan can be produced.

In certain complex areas, such as in way of knuckles or sharp curvature, the amount of input used to define the hull form in HULDEF may be insufficient for satisfactory output from HULSTRX. In these instances, the hull form designer must be informed of the problem and must correct it by supplementing the hull form DGL with additional definition.

Internal information management was another area requiring in-depth analysis. Originally, the hull surface was sectorized to save core; one section of the hull was operated on at a time. This saved core because not all of the hull definition grid lines had to be maintained in current memory. Of course some of the saved core space had to be used to hold the sectoring commands. Large time costs were generated by sectoring the hull because of the frequent sector exchanges necessary to process traces sequentially. Since the total core required to support operation on the sectorized hull was greater than the look limit applicable to many smaller machines, and since the core required to operate on the entire hull at once was within the limits of the larger computers, sectoring was eliminated. This achieved a time saving of about an order of magnitude. Another time consuming file access problem concerned the transverse cut file. An addition to the end of the transverse cut file augmenting the station cuts with cuts at the quarter points between stations was required to ensure satisfaction of trace end point tangency requirements. This was frequently accessed in a non-sequential manner. Since a computer is a digital number cruncher and not a file reader, significant time savings were gained by calculating any needed inter-station transverse cuts on the fly each time they were used. Another order of magnitude of computing time was saved by not bothering to store the augmenting transverse cut file. The elimination of sectoring and the transverse cut file lowered the core requirements to operate on the entire ship to about the original value. Essentially, no penalty was paid for the reduction of CPU time.

## ONGOING DEVELOPMENT

Further development of HULSTRX is currently proceeding in the following areas:

- Trace orientation
- Trace labeling
- Interactive processing
- Multiple line projection

Trace Orientation is being added to the trace definitions so that structural shapes may be added to the drawings in the proper position. The default orientation will be perpendicular to the surface but options will exist to orient the structural shape in an absolute vertical or horizontal position. The orientation of a member is only part of the information needed to draw it. Once the trace orientation is established, the Structural Scantling File will have to be accessed to get the size and shape of the piece.

Trace labeling will make the HULSTRX output more useful. The idea is to print the line name and additional scantling information next to each line on a drawing. This is planned as a development and reference aid.

Interactive processing likewise will make HULSTRX more useful. It will increase the efficiency of a designer who is unfamiliar with the program by prompting him at the appropriate time with the formats and a short description of all inputs necessary to run HULSTRX.

Further development of the multiple line creation portion is underway so that multiple lines may be projected onto the working surface from a different plane, specifically, so that traces may be projected onto the shell from the X, Y or Z planes. This is desirable because, for example, stiffeners on the bottom part of the shell are frequently layed in on a constant Y spacing rather than a constant girth spacing to take advantage of automated production techniques.

## FUTURE DEVELOPMENT

Currently, HULSTRX is being run against real life problems to see where it breaks down or doesn't measure up to standards. The conceptual and detail design of HULSTRX is essentially complete. However, in order to get the maximum utility from the program it must be more fully integrated into the CSD system. Any gains in efficiency attributable to the development of this program can be lost many times over if the output requires laborious conversion of data to match the input requirements of other programs.

Three major areas for development of HULSTRX include:

- Structural Synthesis Design Program (SSDP) interface,
- Structural Scantling File (SSF) development,
- Ship Design Weight Estimate (SDWE) interface.

The first major HULSTRX development area is automated input generation. Hull lines are already fed to HULSTRX from HULDEF through the DGL in digitized form. Structural details are developed in SSDP but must be manually massaged before they can be used as input to the present version of HULSTRX. A computer program which would aid the direct data transfer from SSDP to HULSTRX would eliminate the lengthy, and error-prone manual input method. A task is currently in progress addressing this interface program.

The other major HULSTRX development area is to provide for the description of individual structural members associated with each trace. This would be done by creating a separate structural scantlings file (SSF). The structural scantlings file will refer to the structural arrangement traces in the DGL, and, in conjunction with its scantling data, piece orientation, and other special information (Ref. 7, 8) will provide ship designers and builders with a common data base describing the structural members of a ship. This file could then be used as input to programs which would produce plots of ship

structure with complete labeling and listing of all structures, and to programs which would compute structural weight and moments such as SDWE. HULSTRX will be extended to accomplish this objective as mentioned previously.

When using HULSTRX during the design of a ship, the two structural output files, structural traces and structural details, would be distinct and would be developed interactively rather than sequentially. The designer will first establish the locations of certain key structural members, then their scantlings, and finally resolve any compatibility problems between these members and other parts of the hull structure. Separate plotting (UPL0T) and analysis (SSDP) programs will be used to check the validity of the data placed into the DGL.

The development of the SSDP interface and the portion of HULSTRX which will define the structural scantling file is underway. With the completion of these ongoing tasks, HULSTRX will provide the structural designer with a complete computer aided design package.

## REFERENCES

1. Klomprens, S.H., " HULSTRX-A CASDAC Computer Aid for Hull Structural Contract Design," Proceedings of the REAPS Technical Symposium, 1979.
2. "Engineering Development Plan for the CASDAC Hull Subsystem," Naval Ship Engineering Center, Department of the Navy, Washington, D.C.
3. Aughey, M.C., "Unified Hull Definition System," Proceedings of the REAPS Technical Symposium, June 1975, Palm Beach Shores, Florida. Published by the IIT Research Institute, Chicago, Illinois.
4. "Hull Definition Fairing Program Documentation; Volume I, Introduction; Volume II, Users Manua; Volume III Programmers Manual," U.S. Department of Commerce, Maritime Administration, March 1978.
5. Klomprens, S.H., "Structural Data Base Development-Program HLSTRX Composite Design," HYDRONAUTICS, Incorporated Technical Report 7607.73-1, March 1979.
6. Walz, R.W., Lev, F.M., and Nappi, N.S., "Structural Synthesis Design Program," David W. Taylor Naval Ship Research and Development Center Report 77-0032, December 1977.
7. "Properties of Steel Shapes and Plate-Beam Combinations Used in Shipbuilding," Military (Navy) Handbook, September 1979.
8. "Standard Drawing of Structural Details," New Standard Structural Details under development at NAVSEA.

## APPENDIX A

### ABSTRACT OF RELATED COMPUTER PROGRAMS



DESCRIPTIVE TITLE : DECKING OUT PROGRAM

ACRONYM ..... DEKOUT  
PROGRAM NUMBER ..... 151393  
VERSION ..... 1 1 / 1 2 / 7 6  
AVAILABLE ..... NAVSEA 03R2. WASHINGTON, D. C. 20362  
DEVELOPED BY ..... NAVSEA 3211 (UNDER DEVELOPMENT)  
POINT OF CONTACT . . . . . C. CARLSON SEA 3211, (202) 692-1400  
DOCUMENTATION .....  
SECURITY CLASSIFICATION ... UNCLASSIFIED 0  
PROGRAMMING LANGUAGE(S) ... FORTRAN IV  
COMPUTER VERSION(S) ..... CDC  
DECK SIZE(S) .....  
OBJECT SIZE(S) .....  
SPECIAL HARDWARE ..... GRAPHICS DISPLAY  
SPECIAL SOFTWARE ..... DAM (#530101)  
RUN TIME . TEST DECK .....  
DISTRIBUTION MEDIA ..... MAGNETIC TAPE  
PROGRAM SUMMARY DATE ..... 11 NOV 76

PROGRAM ABSTRACT :

THE DECKING OUT PROGRAM IS USED TO DEFINE THE  
LOCATION OF SUBDIVISION BULKHEADS, AND THE LOCATIONS  
AND GEOMETRY OF DECKS, PLATFORMS, LEVELS, AND THE SUPER-  
STRUCTURE ENVELOPE BY USE OF INTERACTIVE GRAPHICS.

DESCRIPTIVE TITLE : HULL FORM GENERATOR

ACRCNYM ..... HULGEN  
PROGRAM NUMBER ..... I51343  
VERSION .....  
AVAILABLE ..... NAVSEA 03R2, WASHINGTON, D. C. 20362  
  
DEVELOPED BY ..... NAVSEA 312  
  
PGINT OF CONTACT . . . . . F. BJORKFUND SEA 31222. (202) 692-8160  
  
DOCUMENTATION ..... COMPLETE  
SECURITY CLASSIFICATION . . . . UNCLASSIFIED  
PROGRAMING LANGUAGE(S) . . . . FORTRAN IV  
COMPUTER VERSION(S) ..... CDC 6700/TEKTRONIX TERMINAL VERSION  
DECK SIZE(S) ..... 11250  
OBJECT SIZE (S) ..... CM61000  
SPECIAL HARDWARE ..... TEKTRONIX 4015 STORAGE TUBE TERMINAL  
SPECIAL SOFTWARE ..... INTERCOM AND TEKTRONIX PLOT IO GRAPHICS  
RUN TIME TEST DECK ..... 2  
DISTRIBUTION MEDIA ..... MAGNETIC TAPE  
PROGRAM SUMMARY DATE ..... 04 JAN 78

PROGRAM ABSTRACT :

GIVEN THE VERY MINIMUM INPUT OF LENGTH, BEAM, DRAFT, PRISMATIC AND MIDSHIP SECTION, COEFFICIENTS, LCR, LCF, AND A DECK AT EDGE DEFINITION: HULGEN COMPUTES ALL OF THE INITIAL PARAMETERS AND CONTROL CURVES REQUIRED TO PRODUCE A BODY PLAN. THIS BODY PLAN IS NOT THE ONE-DESIRED, BUT PROVIDES A STARTING POINT FOR ANY VARIATIONS THE USER WANTS TO MAKE.

THE SHIP HULL FORM GENERATOR (HULGEN) USES A PIECEWISE POLYNOMIAL DEVELOPMENT AND REPRESENTATION OF AN EARLY STAGE DESIGN SHIP'S BODY PLAN. IT WAS ORIGINALLY WRITTEN FOR REFRESH GRAPHICS SCOWS WITH LIGHT PENS. THOSE EARLIER VERSIONS OF THE PROGRAM ALTHOUGH DONE FOR LIGHT PEN PICKS, OPERATED IN A WAY THAT MADE CONVERSION TO STORAGE TUBE GRAPHICS VERY PRACTICAL. THE DISPLAYS WERE CHANGED VERY LITTLE AND THE INTERACTIVE LIGHT PEN PICKS WERE CONVERTED TO KEYBOARD ENTRY MENUS. THE USER NOW TYPES A MENU OPTION AND/OR DATA TO PROCEED.

HULGEN WAS DEVELOPED SPECIFICALLY FOR THE EARLY STAGE DESIGN PROBLEM OF DEVELOPING MANY OPTIONAL HULLS RAPIDLY. AT THIS PCINT IN THE DESIGN IT IS IMPORTANT TO BE ABLE TO DETERMINE WHETHER THE DESIRED HULL FORM CAN BE DEVELOPED

DESCRIPTIVE TITLE : SHIP HULL CHARACTERISTICS PROGRAM

ACRONYM ..... SHCP  
PROGRAM NUMBER ..... 231072  
VERSION ..... JAN 76  
AVAILABLE ..... NAVSEA 03R2, WASHINGTON, D.C. 20362  
  
DEVELOPED BY ..... NAVAL SEA SYSTEMS COMMAND  
  
POINT OF CONTACT ..... M. AUGHEY SEA. 3212, (202) 692-9070  
  
DOCUMENTATION ..... INCOMPLETE (USER'S MANUAL AVAILABLE)  
SECURITY CLASSIFICATION ..... UNCLASSIFIED  
PROGRAMMING LANGUAGE(S) ..... FORTRAN  
COMPUTER VERSION(S) ..... CDC 6700  
DECK SIZE(S) ..... 10000  
OBJECT SIZE(S) ..... 47500  
SPECIAL HARDWARE ..... CALCOMP PLOTTER (OPTIONAL)  
SPECIAL SOFTWARE ..... CALCOMP  
RUN TIME . TEST DECK ..... 8.9 SEC  
DISTRIBUTION MEDIA ..... TAPE 9 TRACK, 800BPI, UNBLOCKED, CARD IMAGE  
PROGRAM SUMMARY DATE ..... 24 APR 76

PROGRAM ABSTRACT :

SHIP CONSISTS OF A SET OF SUBPROGRAMS WHICH PERFORM THE FOLLOWING NAVAL ARCHITECTURAL CALCULATIONS: HYDROSTATICS, TRIM LINES, LONGITUDINAL STRENGTH, FLOODABLE LENGTH, LIMITING DRAFTS, INTACT STAR., DAMAGED STAR. CROSS CURVES, DAMAGED STATICAL STAR., INTACT STATICAL STAR. ON WAVES.

THESE CALCULATIONS ARE PERFORMED ON A COMMON DATA BASE, THE SHIP DATA TABLE, WHICH IS SET UP FROM THE USER SUPPLIED DESCRIPTION OF THE HULL FORM. EACH SET OF PROPERTIES CALCULATED REQUIRES ITS OWN SET OF INPUT DATA.

ASSUMPTIONS:

- 1 STATION SHAPE ADEQUATELY DESCRIBED BY 2ND ORDER CURVE SEC.
- 2 SIMPSON'S 1-4-1 RULE FOR INTEGRATIONS.
- 3 INTERPOLATIONS OF AREAS AND PROPERTIES DONE BY TAYLORS SECOND ORDER COEFFICIENTS.
- 4 ITERATION FOR BALANCE DONE BY NEWTON-RAPHSON.

THE PROGRAMS WILL CALCULATE DAMAGED COMPARTMENT WATER-PLANE INERTIAS, GENERATE CIRC. OFFSETS. ALLOW FOR INPUT OF APPENDAGES. MANY FLCTS CAN BE GENERATED DEPENDING ON WHICH OPTIONS ARE SELECTED.

DESCRIPTIVE TITLE : SHIP DESIGN WEIGHT ESTIMATE

ACRONYM ..... SO WE  
PROGRAM NUMBER ..... 230021  
VERSION ..... 06/29/78  
AVAILABLE ..... NAVSEA 03R2, WASHINGTON, D. C. 20362  
DEVELOPED BY ..... NAVSEA 3212  
POINT OF CONTACT ..... P. KERN SEA 3212. (202) 692-9070  
DOCUMENTATION ..... COMPLETE, USERS AND PROG. MAINT.  
SECURITY CLASSIFICATION . . . . UNCLASSIFIED  
PROGRAMING LANGUAGE(S) . . . FORTRAN IV AND COMPASS  
COMPUTER VERSION(S) ..... CDC 6700  
DECK SIZE(S) . . . . . 6368  
OBJECT SIZE(S) . . . . . 555008  
SPECIAL HARDWARE . . . . . NONE  
SPECIAL SOFTWARE . . . . . NONE  
RUN TIME - TEST DECK ..... 1 MIN  
DISTRIBUTION MEDIA ..... MAGNETIC TAPE (7 OR 9 TRACK)  
PROGRAM SUMMARY DATE . . . . . 29 JUN 78

PROGRAM ABSTRACT :

THE SHIP DESIGN WEIGHT ESTIMATE COMPUTES PROGRAM SUMMARIZES WEIGHTS AND MOMENTS FROM DETAIL DATA WHICH IS SUPPLIED BY THE USER. THE DETAIL DATA INCLUDES WEIGHT, CENTER OF GRAVITY, DESCRIPTION, 3 CHARACTER CLASSIFICATION GROUP, 2 DIGIT SUBGROUP AND ITEM NUMBER. SUMMARIES OF THE INPUT DATA ARE PROVIDED WHENEVER THE FIRST CHARACTER OR ALL 3 CHARACTERS OF THE GROUP CHANGE OR THE SUBGROUP CHANGES. THE CLASSIFICATION SYSTEMS UPON WHICH THE PROGRAM IS BASED ARE THE NAVY DEPARTMENT SWBS AND BSCI.

ADDITIONAL FEATURES ARE - UP TO 12 LOADING CONDITIONS, MARGINS, HYDROSTATICS COMPUTATIONS BASED ON THE DISPLACEMENT AND LCG OF EACH LOADING CONDITION, LONGITUDINAL WEIGHT DISTRIBUTION, ENGLISH-METRIC UNITS CONVERSIONS AND OTHER MINOR CAPABILITIES.

THIS PROGRAM CAN BE USED IN CONJUNCTION WITH THE SDWE DATA UPDATE PROGRAM (CASDAC MBKQ. 230143) WHICH MANAGES THE DETAIL DATA STORAGE FILE.

DESCRIPTIVE TITLE 1 SHIP SYNTHESIS DESIGN PROGRAM

ACRONYM ..... SSDP  
PROGRAM NUMBER ..... 233021  
VERSION ..... 05-15-70  
AVAILABLE ..... NAVSEA 03R2. WASHINGTON. D. C. 20362  
DEVELOPED BY ..... NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER  
POINT OF CONTACT ..... NAPI/LEV  
DOCUMENTATION ..... COMPLETE - FORMAL  
SECURITY CLASSIFICATION ..... UNCLASSIFIED  
PROGRAMMING LANGUAGE(S) ..... FORTRAN IV  
COMPUTER VERSION(S) ..... CDC 6700  
DECK SIZE(S) ..... 11200  
OBJECT SIZE(S) ..... 250000 OCTAL  
SPECIAL HARDWARE ..... SC4020  
SPECIAL SOFTWARE ..... SC4020  
RUN TIME . TEST DECK .....  
DISTRIBUTION MEDIA ..... MAGNETIC TAPE  
PROGRAM SUMMARY DATE ..... 24 APR 76

PROGRAM ABSTRACT

A COMPUTER PROGRAM DESCRIBED WHICH WILL DESIGN THE LONGITUNINAL SCANTLINGS OF A STEEL MIDSHIP SECTION. ANY PRACTICAL COMBINATIONS OF DECKS. PLATFORMS. AND LONGITUDINAL BULKHEADS FOR THE MIDSHIP SECTION CONFIGURATION MAY BE USED. OPTIONS TO INCLUDE AN INNER BOTTOM STRUCTURE. AND TO PERFORM A NUCLEAR AIR BLAST ANALYSIS OF SHELL AND UPPER STRENGTH DECK STRUCTURE ARE PROVIDED.

THE PROGRAM CONTAINS THE DECISIONS NECESSARY TO DETERMINE AN INITIAL SET OF MINIMUM WEIGHT SCANTLINGS FOR THE SHELL, DECK, BULKHEAD, AND INNER BOTTOM SEGMENTS, TEST THEM TO DETERMINE COMPLIANCE WITH THE DESIGN CRITERIA AS DEFINED BY THE NAVAL SHIP ENGINEERING CENTER. AND THEN INCREASE THE SCANTLINGS IF THE CRITERIA IS NOT SATISFIED. MODIFICATION OF SCANTLINGS CONTINUES UNTIL THE SCANTLINGS DEVELOPED DO NOT CHANGE THE PRIMARY STRESS ASSIGNMENT. IF THE MIDSHIP SECTION HAS A PRIMARY STRESS DEFICIENCY AT THE DECK AND/OR KEEL FIBERS THE PROGRAM WILL AUTOMATICALLY ADJUST THE MATERIAL AT THESE FIBERS AND ITERATE THE DESIGN PROCESS UNTIL SCANTLINGS ARE FOUND THAT ARE OF MINIMUM WEIGHT AND STRUCTURALLY ADEQUATE.

DESCRIPTIVE TITLE : UTILITY DRAFTING ROUTINE

ACRONYM ..... UP LOT  
PROGRAM NUMBER ..... 5201192  
VERSION ..... 01-74  
AVAILABLE ..... NAVSEA C3R2, WASHINGTON, D. C. 20362  
  
DEVELOPED BY ..... AUGHEY SEA 3212  
  
POINT OF CONTACT . . . . . M AUGHEY SEA 3212, (202) 692-9070  
  
DOCUMENTATION ..... COMPLETE  
SECURITY CLASSIFICATION ... UNCLASSIFIED  
PROGRAMMING LANGUAGE(S) ... FORTRAN  
COMPUTER VERSION(S) ..... CDC 6700  
DECK SIZE(S) ..... 2204  
OBJECT SIZE(S) ..... 30000  
SPECIAL HARDWARE ..... CALCOMP/GERBER PLOTTER  
SPECIAL SOFTWARE ..... CALCOMP/GERBER PLOTTER  
RUN TIME . TEST DECK ..... 2.6  
DISTRIBUTION MEDIA ..... MAGNETIC TAPE  
PROGRAM SUMMARY CAT ..... 04-24-76

PROGRAM ABSTRACT :

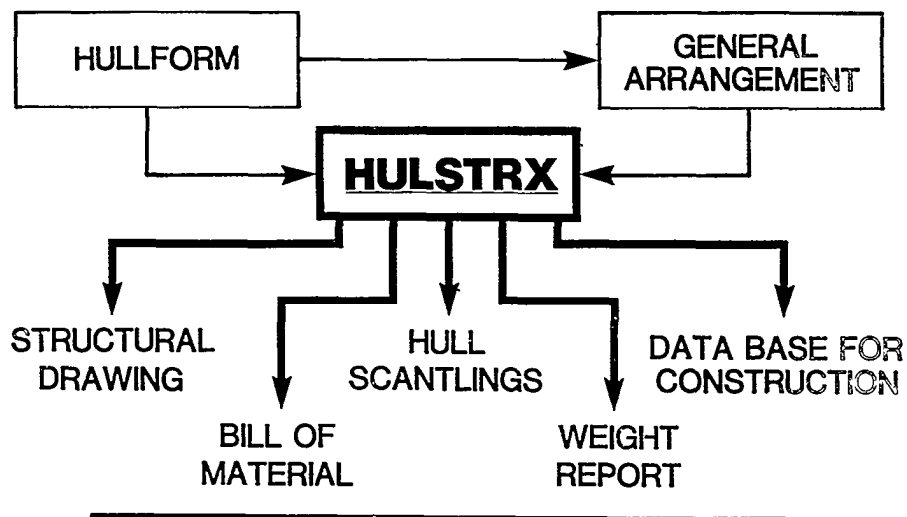
UTILITY PLOT (UP LOT) IS A SIMPLE PROGRAM WHICH ALLOWS  
USERS TO DESCRIBE DRAFTING TYPE PLOTS. THE INPUT DESCRIPTIONS  
OF THE DESIRED DRAWING ARE ON CARDS. THE OUTPUT IS ON CALCOMP OR  
GERBER-TYPE PLOTTERS, WHICHEVER IS AVAILABLE. A CONSIDERABLE  
EFFORT HAS BEEN MADE TO ACHIEVE MACHINE INDEPENDENCE. THE THREE  
VERSIONS (IBM 1130, CDC 6700/CALCOMP, CDC 6700/GERBER) WILL ALL  
PRODUCE SIMILAR PLOTS FROM THE SAME DATA, AND 'EXCEPT FOR THE  
PLOTTER INTERFACE ROUTINES. THE FORTRAN PROGRAMS ARE A VERY LIMITED  
SUBSET OF BASIC FORTRAN. ONCE DESCRIBED ON THE INPUT CARDS, EACH  
"TEMPLATE." BECOMES, MORE OR LESS PAYMENT AND CAN BE USED AS A  
BASE TO BUILD UPON OR OVERLAY OTHER DRAWING INFORMATION. THIS  
PERMITS COMPLEX DRAWINGS TO BE BUILT UP OVER A PERIOD OF TIME AND  
COMPONENTS OF THOSE DRAWINGS TO BE USED REPEATEDLY.

APPENDIX B  
VIEWGRAPHS FROM PRESENTATION

U.S. NAVY  
CAD/CAM PROGRAM  
HULL STRUCTURE

**HULSTRX**

**HULSTRX USN CSD SUBSYSTEM**



## HULSTRX INTRODUCTION

- INITIAL DEVELOPMENT UNDER CASDAC
    - NAVY'S COMPUTER AIDED SHIP DESIGN AND CONSTRUCTION PROJECT
    - 1979
  - ONGOING DEVELOPMENT UNDER CSD
    - NAVY'S COMPUTER SUPPORTED DESIGN PROJECT
- 

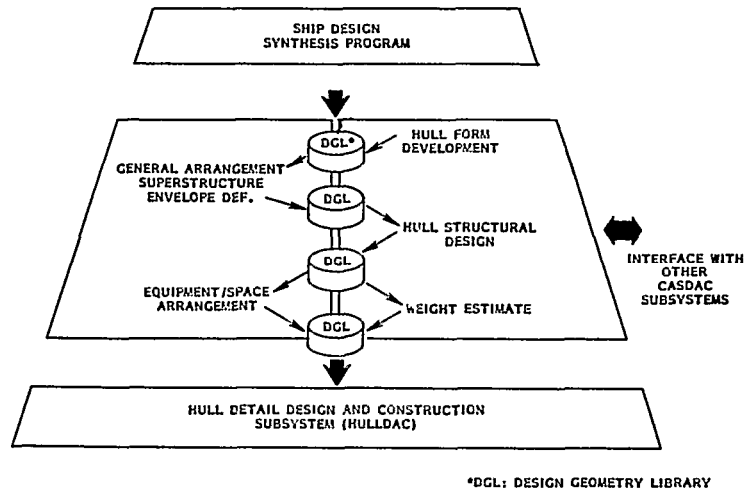
## HULSTRX INTRODUCTION

### n OBJECTIVE OF PRESENTATION

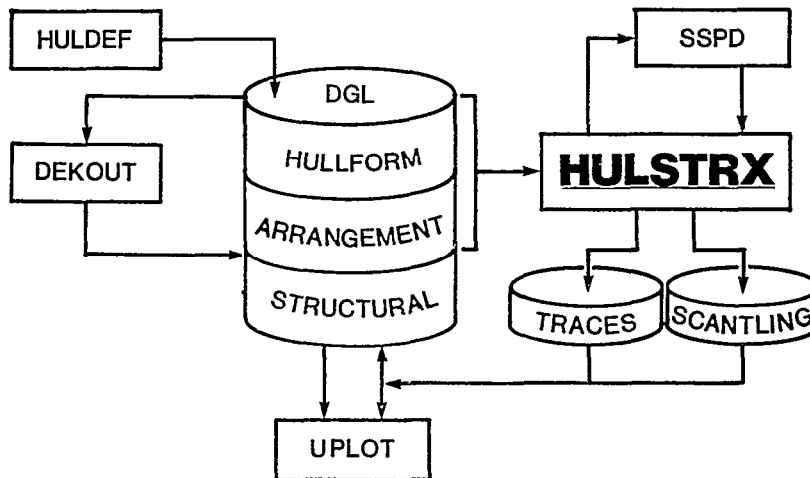
- REVIEW DESIRED CAPABILITIES
  - DEMONSTRATE PRESENT CAPABILITIES
  - DISCUSS ONGOING AND FUTURE DEVELOPMENT
-



## HULSTRX THE NAVY CSD SYSTEM



## HULSTRX CSD'S STRUCTURAL PORTION



## HULSTRX DESIGN CONSIDERATIONS

- CONCEPTS USED IN PARALLEL WITH HULDEF
  - FILE STRUCTURE AND FORMAT OF DGL
  - PARAMETRIC SPLINE FOR REPRESENTING 3-D LINES
  - OPERATION IN BATCH MODE

## HULSTRX THE NAVY CSD SYSTEM

### n STRUCTURAL DGL

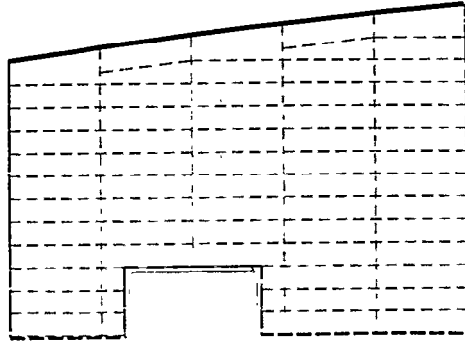
- INPUT FOR STRUCTURAL DESIGN PROGRAMS
- BASIS FOR COMPUTER GENERATED DRAWINGS
- AS A DESIGN DELIVERABLE ITSELF

## HULSTRX OBJECTIVES

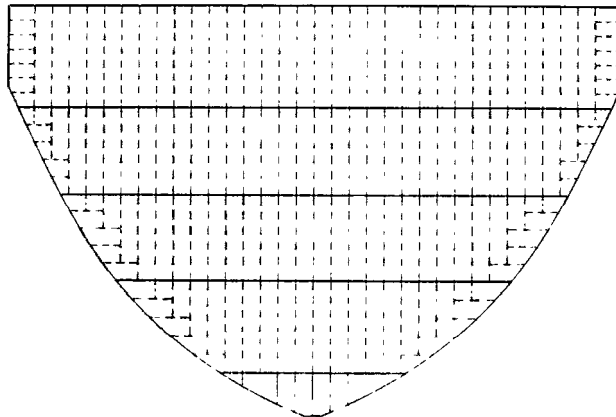
### n CURRENT OBJECTIVES

- SHELL EXPANSION DRAWINGS
  - DECK DRAWINGS
  - BULKHEAD DRAWINGS
  - SECTION DRAWINGS
  - STRUCTURAL DATA BASE
- } [INCLUDING  
SUPERSTRUCTURE

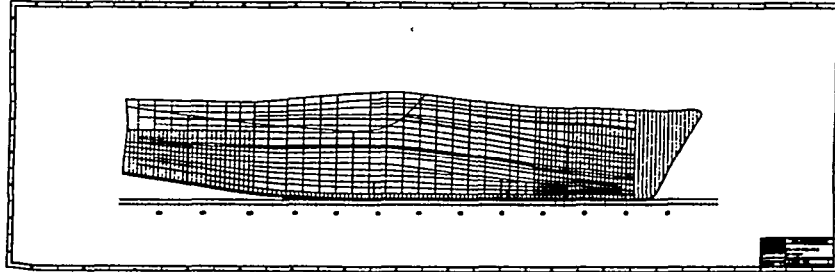
## **HULSTRX STATUS REVIEW**



## **HULSTRX STATUS REVIEW**



## HULSTRX STATUS REVIEW



## HULSTRX OUTPUT; SHELL EXPANSION

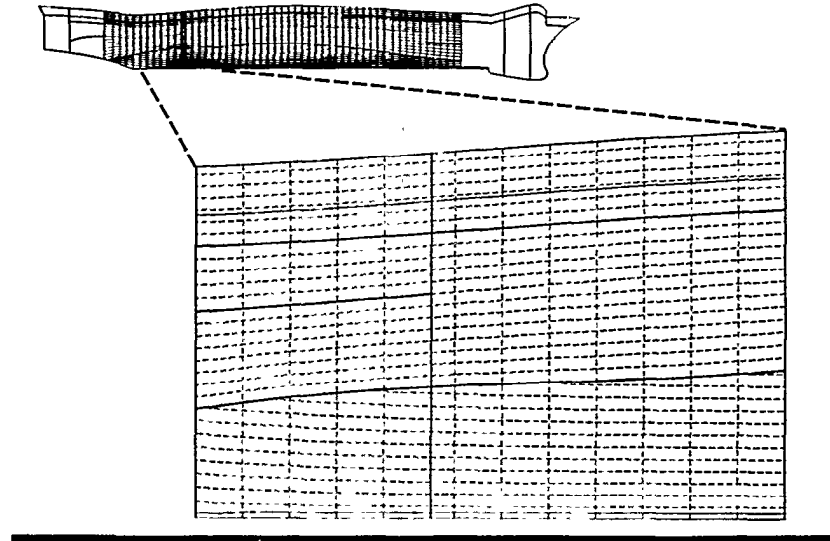


```

01 SURFACE SHOWN          DATE 8/11/81
02 EXP
1312 N 13 SP .5 18 CLO000 18 600000 1 180025 1 180129
4P ST2000 LB5001 ST5002 180001 LB5004 LB5005 ST5006
4P LB5007 ST5008 LB5009 ST5010 LB5011 ST5012
1314 N 7 18 LB0008 18 LB0001 1 180025 1 180129 ST0000
1314 N 4 18 LB0001 18 LB0002 1 180025 1 180129 ST1000
1314 N 6 BP .5 18 LB0000 18 LB0002 1 180025 1 180129 ST2000
1341 N 32 18 180025 18 180129 1 CLO000 1 LB0000 ST3000
99
  
```

## **HULSTRX OUTPUT; SHELL EXPANSION**

### **DETAIL**



## **HULSTRX**

### **GROUND RULES FOR DEVELOPMENT**

- HULDEF: POINT OF DEPARTURE
  - DGL FILE STRUCTURE AND FORMAT
  - PARAMETRIC SPLINE FOR 3-D LINE REPRESENTATION
  - END POINT TANGENT DEFINITION FOR LINE SEGMENTS
- COMPATIBILITY WITH OTHER EXISTING CSD PROGRAMS (SSDP, SHCP, ETC.)
- (INITIALLY:) BATCH MODE OPERATION

## HULSTRX OPERATIONAL ASPECTS

### ■ DGL STRUCTURE

SHIP, DATE

SURFACE NAME  
TRACES IN END  
PT/TANGENT FORM

BLANK RECORD

SURFACE NAME  
TRACES

BLANK RECORD

■  
■  
■

LAST SURFACE

BLANK RECORD  
BLANK RECORD  
EOF

## HULSTRX OPERATIONAL ASPECTS

### ■ LINE TYPES & MNEMONIC IDENTIFIERS

#### SHELL GEOMETRY TRACES

FORM LINE  
GIRTH LINE  
CONTROL LINE  
DISPLAY LINE  
STATION  
FRAME  
WATERLINE  
BUTTOCK  
DIAGONALS

#### IDENTIFIER

F-----  
G-----  
C-----  
D-----  
STA---  
FR-----  
WL-----  
BT-----  
DI-----

#### ARRANGEMENT TRACES

TRANSVERSE BULKHEAD  
WEB FRAMES  
DECK  
PLATFORMS  
FLATS  
LONGITUDINAL BULKHEAD  
SKEW BULKHEAD

TB-----  
WF-----  
DK-----  
PF-----  
FL-----  
LB-----  
SB-----

#### STRUCTURAL TRACES

STIFFENER  
SEAM  
BUTT  
MASTER BUTT  
HEADERS

#### IDENTIFIER

ST----  
SM----  
BU----  
MB----  
HR----

#### SURFACE NAMES AND TRACES

SHELL (PORT)  
SHELL (STARBOARD)  
GIRDER  
JOINER BULKHEAD

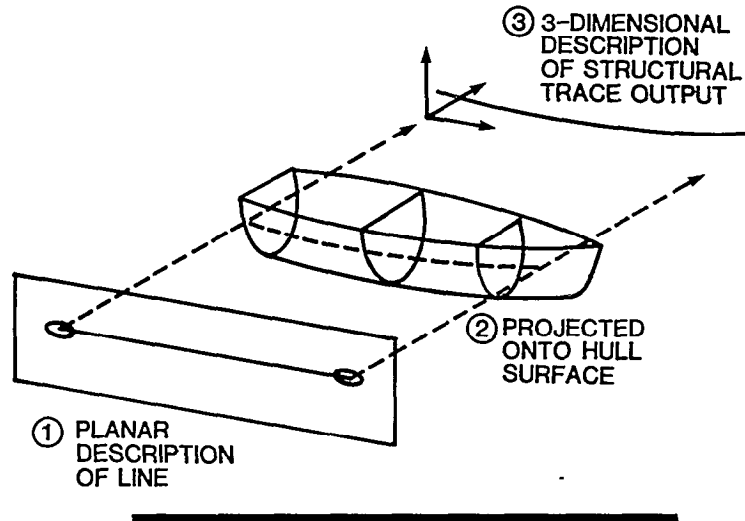
SH---P  
SH---S  
GR----  
JB----

#### MISCELLANEOUS STRUCTURAL NAMES

PLATE  
PIECE  
HOLE  
BREAST HOOK  
FASHION PLATE  
INNER BOTTOM  
SUB-ASSEMBLY  
CHOCK  
BRACKET  
JEB  
FLANGE  
ANCHOR RECESS  
APPENDAGE

PL-----  
PC-----  
HL-----  
BH-----  
FP-----  
IB-----  
SA-----  
CK-----  
BK-----  
WE-----  
FG-----  
AN-----  
AP-----

## HULSTRX INPUT OPTION



## HULSTRX INPUT OPTION

### ■ AVAILABLE INPUT OPINIONS

- PROJECT FROM X-PLANE
- PROJECT FROM Y-PLANE ◀
- PROJECT FROM Z-PLANE
- PROJECT FROM GIRTH-PLANE
- LAY IN MULTIPLE EQUALLY SPACED  
LINES FROM ANY PLANE
- LAY IN MULTIPLE EVENLY SPACED  
LINES FROM ANY PLANE
- BEGIN OR END LINE ON PREVIOUSLY  
DEFINED TRACE
- DEFINE START OR END TANGENTS

# HULSTRX INPUT FILE



## INPUT CARDS

```
01 SURFACE SH0005 DATE 0/11/81
02 EXPT
1512 N 13 SP -3 IB CL0000 IB BK0000 I TB0025 I TB0129
49 ST0000 LB5001 ST5002 LB7003 ST5004 LB5003 ST5006
49 LB5007 ST5008 LB5009 ST5010 LB5011 ST5012
1514 N 7 IB BK0000 IB BK0003 I TB0025 I TB0129 ST0000
1514 N 4 IB BK0003 IB BK0002 I TB0025 I TB0129 ST0000
1514 N 4 SP -3 IB CL0000 IB BK0002 I TB0025 I TB0129 ST0000
1541 N 52 IB TB0025 IB TB0129 I CL0000 I CL0000 ST0000
99
```

## 10 LINES

# HULSTRX INPUT ILLUSTRATION

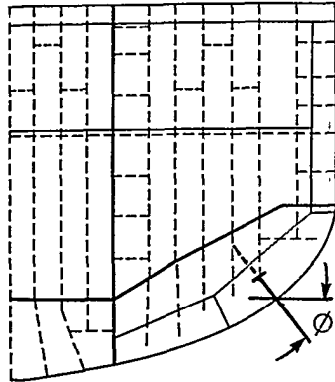


```
01 SURFACE SH0005 DATE 0/11/81
02 EXPT
1512 N 13 SP -3 IB CL0000 IB BK0000 I TB0025 I TB0129
49 ST0000 LB5001 ST5002 LB7003 ST5004 LB5003 ST5006
49 LB5007 ST5008 LB5009 ST5010 LB5011 ST5012
1514 N 7 IB BK0000 IB BK0003 I TB0025 I TB0129 ST0000
1514 N 4 IB BK0003 IB BK0002 I TB0025 I TB0129 ST0000
1514 N 4 SP -3 IB CL0000 IB BK0002 I TB0025 I TB0129 ST0000
1541 N 52 IB TB0025 IB TB0129 I CL0000 I CL0000 ST0000
99
```

1514 N 7 IB BK0000 IB BK0003 I TB0025 I TB0129 ST0000



## **HULSTRX ONGOING DEVELOPMENT**



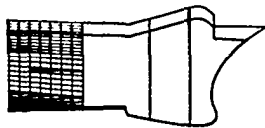
- TRACE ORIENTATION
- TRACE LABELING
- STIFFENER DEFINITION (FROM SSF)

---

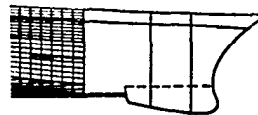
## **HULSTRX ONGOING DEVELOPMENT**

### GIRTH DISTORTIONS

CURRENT



UNDER  
DEVELOPMENT



## **HULSTRX FUTURE DEVELOPMENT**

### **n AREAS OF FUTURE HULSTRX DEVELOPMENT**

- STRUCTURAL SYNTHESIS DESIGN PROGRAM (SSDP) INTERFACE
- STRUCTURAL SCANTLING FILE (SSF) DEVELOPMENT
- SHIP DESIGN WEIGHTS ESTIMATE (SDWE) INTERFACE
- BILL OF MATERIAL

## **HULSTRX SUMMARY**

### **n ONE, DATA BASE FOR HULL DESIGN:**

#### **INHERENT CONSISTENCY OF SHIP**

- DESIGN DISCIPLINES (HULL FORM ARRANGEMENTS, STRUCTURES, ETC.)
- DESIGN REPRESENTATIONS (DECK, BULKHEADS, SHELL, ETC.)

### **n COMPUTER-AIDED DRAFTING:**

#### **ACCURACY AND LEGIBILITY**

- ▶EASY SCALE ADJUSTMENT/MULTIPLE USE
- ▶INCREASED EFFICIENCY AND VERSATILITY

### **n INTEGRATED WITH EXISTING PROGRAMS UNDER CSD**

## BRITSHIPS--SHIPBUILDING CAD/CAM IN PRODUCTIVE APPLICATION

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### ABSTRACT

BRITSHIPS is the generic title for a computer system built from related ship design/production software created by the British Ship Research Association (BSRA). The integrated system has been the subject of continuous development since it first went into use in the late 1960s, and won a Queen's Award to Industry for technological innovation in 1974. BSRA is the central research and development agency for the British shipbuilding industry. BRITSHIPS has been developed in close consultation with the industry and is a reflection of the practical needs of the shipbuilders. The system is constantly updated in line with advances in design and production technology, advances in computing methods, and the developing requirements of the shipbuilding community.

This paper describes the structure and organization of the system, and the facilities it offers.

## ABOUT BSRA

The British Ship Research Association (BSRA) is one of the largest research organisations in the world devoted to marine technology. Its staff of some 200 includes naval architects, marine engineers, mechanical engineers, physicists, chemists, mathematicians, computer specialists and economists all with specialist knowledge of the marine application of their subject.

Since its foundation in 1944, BSRA has conducted a planned programme of research to advance ship and shipbuilding technology. The knowledge and experience gained embraces virtually every aspect of marine technology: hydrodynamics, structures, engineering systems, automation, shipbuilding technology, vibration and noise reduction, anti-corrosion and anti-fouling techniques, computer applications and management aids.

BSRA's experience in the application of computers to routine ship design office calculations extends over a quarter of a century. In the 1960's BSRA pioneered interactive computing, using on-line terminals for these calculations. UK Shipbuilders were quick to appreciate the advantage of this method of working. Batch processing provides a means of validating a proposed design but interactive operation enables the programs to be used creatively while the design is being evolved and has resulted in a more rational approach to the design process.

A further development was the BRITSHIPS Suite which comprises a comprehensive set of computer programs for ship design and production. More recently a computer-based system for the design, detailing and generation of production information has been developed based on interactive computer graphics.

BSRA computing facilities include:

On-line access to a range of mainframe computers including a large IBM and an ICL 1904s on site providing dial-up service.

DEC PDP 11/45 and 11/40 minis with interactive graphics terminals.

A range of microcomputers, including Alpha LSI/20, Ferranti F100L, Altos Series 8000.

Redifon Ci5000 hybrid digital/analogue system.

supported by:

Kongsberg DC 300F/1845 draughting system.

Applicon AGS 800 interactive design and draughting system.

In addition to the research departments there is also a large Technical Services department which offers a wide range of technical services, in support of marine technology, on a contract basis world wide. BSRA Technical Services support operators, builders and designers of ships and other marine structures in a number of ways:

Information services

Design support

Shipboard engineering and automation

Noise and vibration

Corrosion and fouling

Ship trials

Service performance  
Shipyard methods  
Measurement and instrumentation  
Computing facilities, and  
Computing packages.

In addition BSRA manufactures and supplies hull roughness analyser gauges for the quantitative assessment of hull surface condition. The SFOLDS, ship design analysis programs are supplied with an ALTOS micro-computer as a complete hardware/software package.

## 1 INTRODUCTION

BRITSHIPS has been used, as an integral part of their design and production procedures, by UK shipyards for a number of years, some of the BRITSHIPS modules are also used overseas. It consists of a comprehensive system of computer programs for ship design and the support of ship production using modern methods of manufacture with numerically controlled (NC) machine tools. BRITSHIPS has been developed with the practical assistance of shipbuilding managers and combines the expertise and experience of these people with up-to-date computer technology.

The BRITSHIPS system and the tasks performed by each of the major modules which it comprises are described in Section 2. In Section 3 the use of the system is traced through the development of a hull form design, the definition of the steelwork parts and the output of technical information required for manufacture and machine control data.

A list of the design analysis programs, known as SFOLDS, together with a short description of each program, is contained in Appendix 1.

## 2 BRITSHIPS - SYSTEM OUTLINE

### 2.1 The Modules

The system, see Fig.1, consists of six major modules linked through common data files which constitute the system data store. Each module may be run as a self contained sub-system. This means that it is not necessary to implement all the modules at the same time or in the same location although in practice certain groups of modules would normally be run together.

The shipyard may select the modules most relevant to its needs and may implement them progressively.

The modules are:

<u>MODULE</u>	<u>MODULE NAME</u>	<u>TASKS PERFORMED</u>
T100	SFOLDS (ship Form on-Line Design System)	Routine ship design calculations
T110	BRITFORM	Generation of hull form geometry
T200	BRITFAIR	Lines fairing, and production definition of hull form
T300	BRITSHELL	Shell arrangement, longitudinal definition and plate development
T400	GOLD (geometric on-Line Definition)	Interactive definition of steelwork piece parts and solution of design problems in geometry
T410	GOLDNEST	Interactive nesting of piece parts within a rectangular plate and defining of cutting sequence

## 2.2 SFOLDS

SFOLDS is a suite of programs for ship design office calculations which are arranged for use either in conventional batch processing mode or interactively on-line from a computer terminal.

Programs are provided for hydrostatics, stability, longitudinal strength, tank calibration, launching, grain calculations etc. Other programs enable preliminary offsets and lines drawings to be generated for forms conforming to the Revised-and Improved BSRA standard series. For these forms powering data can also be derived based on comprehensive model tests for the series.

SFOLDS programs use a common hull form definition to minimise data preparation. When the design has been finalised the offset data are transferred to the system data store for lofting by the BRITFAIR system.

The main SFOLDS programs offer the user a choice of output options at run time and there are programs for listing outputs in special formats e.g. HYTAB and KNTAB (Appendix 1). Any of the data stored on file may be selectively listed.

The SFOLDS programs which are now in regular daily use by over 50 organisations throughout the World are written in a highly portable version of FORTRAN IV and have been implemented on the following different computers:

- IBM System 370
- ICL 1900 series
- ICL 2900 new range including 2903 and 2904
- Honeywell 2000 series
- Honeywell 6000 series
- GE 400
- Univac 1100
- Prime
- Hewlett Packard 2000
- Control Data Cyber 170 Series



The SFOLDS module comprises the programs listed in Appendix 1. Additional programs dealing with seakeeping, vibration, propeller design etc., are also available.

### 2.3 BRITFORM

BRITFORM is based on the hull form design phase of the FORAN system and allows the rapid design of hull forms without the need for manual drawing and fairing of the ship's lines. By utilising the interface with BRITFAIR, production details can be readily incorporated into the design.

BRITFORM is an integrated suite of programs allowing designers:

- to create entirely new mathematically smooth hull forms from a basic description of the geometry of the ship,

- to alter a previous design to incorporate modified design criteria,

- to obtain a mathematically smooth hull definition from a sketch design,

- to check the hydrostatic particulars,

- to define the deck arrangement.

The results are presented graphically where appropriate and, because of the mathematical nature of the surface definition, the hull definition at frame sections can be obtained immediately the design is acceptable.

Figure 2 shows the building frames and Fig.3 the outline general arrangement for a design generated by BRITFORM

The interface with BRITFAIR can be used to introduce, more flexibly, production details and is a necessary link to the BRITSELL and GOLD Modules.

## 2.4 BRITFAIR

BRITFAIR is the lines fairing, hull surface definition and interpolation module, and performs the lofting functions of:

- fairing the lines,

- adjustment of the form to accommodate constructional details at stem and stern,

- incorporation of production engineering requirements such as flat areas and knuckles,

- definition of decks, flats, stringers, hopper tanks and other intersections with the moulded surface,

- interpolation of building frames,

- deformation of an existing hull form.

The module is preferably used interactively from a terminal since this gives the user maximum control over the processes.

Figure 4 is an example of the production level definition created for a bulk carrier using BRITFAIR.

BRITFAIR takes in offset data defining the hull form at the normal design level of detail (e.g. as used for making the tank model) and outputs a complete production definition. BRITFAIR creates a series of structured data files which are subsequently accessed by the BRITSHELL and GOLD modules.

Processing by BRITFAIR to create these files in the data store is essential to the application of BRITSHELL and the optimum use of GOLD in piece-part definition.

The data on file may be displayed graphically in various forms of drawing, on any required scale and the detailed numerical information available in the 'loft books' is output by the system.

## 2.5 BRITSHELL

BRITSHELL is the Shell and Longitudinal Definition Module and is used to:

- define and verify the seams, butts, longitudinals or any general line on the hull surface,

- describe the straking arrangement, and

- develop the shell plates and produce the NC tapes and listings for plate cutting,

- generate manufacturing statistics such as length of profile, percent scrap,

- generate shell jig setting information.

Typically the procedure for using BRITSHELL is for the positions of the seams and longitudinals to be obtained from the plate edge body plan and shell expansion drawing. These lines are adjusted and verified by use of the BRITSHELL facilities and then the individual plates which constitute each strake are identified to the system using the simple user language which minimises the amount of numerical data that has to be supplied.

Typical output for the shell arrangement, longitudinals and deck-at-side lines is shown in Fig. 5.

The shell arrangement already defined will be used as a basis for the development of the shell plates and the generation of plate marking information through a further application of the BRITSELL input language. A plate may have up to seven sides. There is also provision for specifying the plate thickness and the grade of steel to be used. A margin of additional material which can be trimmed during erection may be specified on one or more sides. The cutting margin is also specified for each batch of plates. This is the amount by which the nominal length and breadth of the ordered plate should exceed the theoretical dimensions of the minimum circumscribing rectangle. It provides for the width of the cut and allows for any mal-alignment of the plate on the burning table and for departures from the nominal dimensions. A marking statement specifies which of the lines already defined on the moulded surface should be transferred to the developed plate. Figure 6 shows a check drawing of a developed plate (produced on the screen of a display terminal with annotations indicating the significance of the various lines shown). Steel/ordering information and plate preparation statistics (Fig. 7) will be generated for each developed plate. Depending on the method of flame cutting used in the shipyard the actual manufacturing data output will consist of either an NC machine control tape, an optical template drawing, or a tabular statement of co-ordinates for manual marking. The same procedures will be used for the development of any longitudinals which do not lie in one plane.

Rolling set information can be drawn on the plate itself from the NC tape. Alternatively this information can be output in tabular form.

BRITSELL also generates the Longitudinal Information Files necessary for the automatic notching facility of the GOLD processor.

## 2.6 GOLD

GOLD is the piece parts definition, nesting and general geometric problem solving module.

GOLD (Geometrical On-Line Definition) forms the parts definition module of the system, and takes advantage of the latest developments in language processing techniques to provide a system which may be used either in conventional batch mode or on-line from an interactive graphics terminal.

There are two approaches to part programming, the first requires detailed information for each part in the form of working drawings. This information is then coded as a set of unique instructions which result in the replication of the original information in the form of a drawing or control tape. The other approach is to use a system for defining the part geometry in algorithmic form, i.e. it is the method of constructing the geometry which is defined to the computer rather than the actual shape of the individual part. Most practical systems contain elements of both methods. The first is of course simplest to comprehend, but can become tedious and there will be no saving in time compared with graphical methods, but there may be an improvement in accuracy. The advantage of the second approach is that instructions can be prepared for standard configurations, and used again and again with different dimensional data. These may be at various levels ranging from standard details for cutouts and brackets, to repetitive arrangements that may occur in several ships or components that simply change in shape at different stations within one ship.

GOLD allows a gradual progression from the first approach to the algorithmic mode. Initially, part-programmers coding individual parts from fully dimensioned drawings need only be instructed in a few simple statements defining points, circles and contours. These enable quite complex shapes to be defined by terse statements which specify dimensional data for the key features of the outline. As they progress to more general

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work, part-programmers may be introduced to the geometry and logical features which allow parts to be defined in terms of more basic data and construction rules. Those concerned with the development of standardized definitions for general use or with design applications will need to draw on the full potential of the system for specifying geometry in algorithmic terms.

The development of algorithmic definitions for standard arrangements has close analogies with the writing of simple computer programs and the work is greatly facilitated through the use of an interactive on-line system which provides immediate validation of each line of instructions as it is input. GOLD may be used on-line from a remote access terminal when complex standard definitions are to be created while processing the main volume of work in batch mode.

The geometry of the faired hull form and structural arrangement defined by BRITFAIR and BRITSELL is accessible to GOLD. Elements of this geometry may be referenced by name when writing parts descriptions and require no further definition. Frame shapes and the points at which each longitudinal intersects a transverse frame may be referenced in this way. The stored longitudinal scantling information enables the appropriate 'notch' profile to be generated automatically where transverse webs are penetrated by longitudinal stiffeners. The dimensions of the notch will be adjusted by the system to allow for the obliquity of the bar at the point where it passes through the transverse material.

A further development has been to reduce the extent of part programming instructions needed to define large steelwork components with many detail cutouts. Often-used cutouts required for drainage, passage of stiffening members etc. are described in part programming language by the use of macros. In normal circumstances, these are called as required each time the detail occurs, and obviate the need to part program the cutout each time.

Common practice is to build the description of a new component calling the system macros as necessary, and describe the remaining outline in part programming language by reference to the hull file, or by defining the boundaries.

The Structural Part Macros (SPM) development is in effect a suite of large macro programs, defining items such as floors or longitudinal girders in double bottom structure. Programs have been created, whereby the parts programmer can call the relevant SPM full description, and by defining a small number of parameters create the complete part description. The computer program is used interactively with the hull file, GOLD system, and existing low complexity macros. The output from the SPM is produced directly on a punched paper tape for the numerical-control profiling machines, or as optical 1/10 scale templates as defined by the user.

Further work is continuing in this concept, and it is proposed that more major components will be added to the parts library of this broader application of the BRITSHIPS System.

The power of the GOLD system extends its use beyond parts definition to general design problems involving complicated geometry geometry.

## 2.7 GOLDNEST

GOLDNEST is the module for the interactive nesting of piece parts. Parts may be nested as they are programmed or they may be stored and the nesting done later using a separate interactive nesting facility GOLDNEST. This operates as a post processor and does not require the reprocessing of the original part programs.

Certain properties of the parts such as the length of profile and weight are calculated and stored along with the grade of material, thickness and the completed definition of the part. These are used by GOLDNEST to generate manufacturing statistics.



GOLDNEST is operated from an interactive terminal equipped with either a display screen or an A3 size plotter. The outlines of parts to be nested together are displayed and by means of simple instructions input at the keyboard and the use of a cursor on the screen or plotter table, the required positions of the parts are indicated. Parts may then be repositioned until a satisfactory nesting has been achieved. Parts may be replicated or mirrored as required in the course of nesting. Finally the order in which the parts are to be cut is indicated. Figure 8 shows the result of a nesting as it appears on the plotter. The broken lines represent rapid movement of the cutting head between marking and burning operations. The output from GOLDNEST is a file of cutter location data for the nested arrangement. This is then post-processed to produce machine control instructions for either an NC machine or a drafting machine on which an optical template is to be drawn.

Various auxiliary programs may also be brought into use for example, to generate the marking information required for the bending of frames by the inverse line method or to provide the data required for setting pillar jigs for curved assemblies.

### 3 BRITSHIPS IN APPLICATION

The BRITSHIPS Modules are used in various ways in the development of a ship design from initial concept to the output of the detailed information required for manufacture. The process is conveniently considered in four main phases:

Concept Design - the development of the initial concept and assessment of its feasibility.

Contract Design - complete specification of the design in all its functional aspects.

Production Definition - including the specification of fabrication details.

Preparation of Manufacturing Information - drawings, tabulated data, NC tapes.

#### 3.1 Concept Design

In this phase the main hull form parameters are established and use is made of various programs in the SFOLDS module.

Using the BSRA Standard Series program MSHF a basis form may be created having the proposed dimensions and form coefficients. This form will then be evaluated using the various design analysis programs hydrostatics, stability, powering etc.

If the form does not satisfy all of the design requirements it may be modified by use of the form distortion program DEFORM which applies the classical form distortion procedures such as 'one-minus-prismatic'. The design analysis programs may then be used to re-evaluate the modified form and the process continued until a satisfactory solution is reached.

The whole process is carried out within the computer but under the control of the designer using a remote access terminal. Computer files are used to transfer data between programs but tabular listings and drawings may be output for assessment at any stage.

### 3.2 Contract Design

The Standard Series form is a satisfactory basis for all the preliminary calculations but a standard form can rarely be used in the final design without local modification. Such features as propeller aperture, bow form and flare may need to be adjusted to the particular requirements of the design. The BRITFORM module provides the flexibility required for such adjustments. A particularised version of the form is therefore generated using BRITFORM.

The design analysis programs will again be used to evaluate the new form and the calculations will be carried out in a greater depth of detail. A model cutting drawing will then be generated for use by the experiment tank. If, as a result of tank model tests, further modifications are required, these can be made quickly by a further application of BRITFORM.

When a fully acceptable hull form design has been achieved an outline general arrangement, profile and decks, Fig.3 will be produced and a preliminary building frame body plan, Fig.2, usually on 1/25th scale, will be generated as a basis for steelwork design and engine room arrangement.

GOLD may also be used during this phase to solve such problems as the establishment of stern frame geometry in relation to the required propeller clearances.

### 3.3 Production Definition

Hull forms designed using BRITFORM are defined mathematically and are therefore completely fair. However, local modification is invariably required to incorporate the engineering details of stern frame and bow construction. Control at this level of detail is achieved through the BRITFAIR module. At the same time more subtle changes may be introduced to ease production, for example, framing which is nearly straight in the mathematical definition may be made completely straight where this can be done without detriment to the hydrodynamic characteristics.

Where the design has been prepared manually for some reason, BRITFAIR is used to fair the whole surface and create a definition at the level of precision required for production.

The shell plating arrangement will be defined precisely using the BRITSHELL system and definition language.

The arrangement of longitudinals, stringers and girders on the moulded form will also be defined using BRITSHELL. A schedule of scantlings of longitudinals will be created and stored for subsequent access by the GOLD processor when generating the appropriate notch forms for penetrations by longitudinals in transverse components.

GOLD will be used to define the detailed geometry of structural components and in particular to prepare macros or standard definitions for components for which the same basic design is to be used at several points in the structure.

### 3.4 Manufacturing Information

The shell arrangement already defined will be used as a basis for the development of the shell plates and the generation of plate marking information through a further application of the BRIT SHELL input language.

The main application of GOLD will be in this phase. The geometry of the individual piece parts and their cutting sequences will be defined and processed to create standard APT cutter location data. For parts that are to be nested these data will be called from the data store for processing by GOLDNEST.

The output from GOLDNEST is a file of cutter location data for the nested arrangement. This is then post-processed to produce machine control instructions for either an NC machine or a drafting machine on which an optical template is to be drawn.

Various auxiliary programs may also be brought into use for example, to generate the marking information required for the bending of frames by the inverse line method or to provide the data required for setting pillar jigs for curved assemblies.

#### 4, FUTURE DEVELOPMENTS IN BRITSHIPS

Since 1968 a major portion of the UK Shipbuilding Industry has been using BRITSHIPS with its numerical methods to assist in the definition of the hull form and the definition of piece-parts. A logical extension of the system is to integrate the steelwork design and drawing office functions with the lofting activities using interactive draughting techniques. A development along these lines has been jointly carried out by Swan Hunter Shipbuilders and BSRA, under the sponsorship of British Shipbuilders. This new development is to be known as BRITSHIPS II to distinguish it from the earlier system.

BRITSHIPS II will incorporate an interactive draughting module and this will be the designer's principal means of communicating with the system. For the implementation at Swan Hunter Shipbuilders the CADAM interactive draughting package will be used..

Computer graphics can significantly improve productivity in the production and modification of the several hundred drawings required to communicate design information to the customer, regulatory authorities and the shipyard's own production departments. A more important benefit from a shipbuilder's point of view derives from the fact that drawings created using a graphics system are stored in a machine-readable form as computer files: geometrical, numerical and text data once created in a drawing may therefore be used in other computer processes. BRITSHIPS II provides a software system which enables the drawing data, produced by the draughting module, to be used directly for technical and administrative purposes.

The interfaces between BRITSHIPS II and BRITSHIPS I and other systems are shown in the schematic information flow diagram, Fig.9. Figure 10 presents an overview of the BRITSHIPS II software together with the interactive graphics data base and the BRITSHIPS II data store.

In the preliminary design phase the 3-dimensional geometry of the hull form and the moulded lines of the primary structure will be created using an extension of BRITSHIPS I techniques. Interface programs will make it possible to incorporate data relevant to the hull form definition and compartmentation generated during the preliminary design phase.

In the scantling phase 'designers and draughtsmen will use the draughting system in conjunction with the moulded outlines for the construction of scantling plans. Programs will also be available to perform the various calculations required to be made in the course of preparing scantling drawings. Information extracted from drawings produced by the graphics system will be processed to create and add to the 3-dimensional model in the BRITSHIPS II data store, a representation of the shell seams and butts, and the moulded lines of longitudinals, stringers and girders. Facilities will be available for extracting steel requisition data from the scantling drawings.

The draughting system will enable the drawings produced during the scantling phase to be developed as detail steelwork drawings, avoiding the re-drawing necessary in manual systems. A library of standard details will be available which will encourage the use of properly engineered details throughout the design. Existing software (GOLD) will enable standard longitudinal notches to be generated and automatically sized positioned and orientated on the drawing. The output from the detail design phase will consist of detailed steelwork and production drawings for each unit, assembly and sub-assembly.

The interactive draughting system will be used to extract the piece-part geometry from the detail drawings and add other necessary information, e.g. edge preparation details. Nesting will be accomplished using the interactive version of GOLD and the part-programming operation will be reduced to the specification of cutting sequences and burning machine functions. Control tapes will be generated by the available BRITSHIPS I software.

Technical and planning information for production will be derived from the output of the detail design and piece-part separation phases. It will include structured lists of assemblies, sub-assemblies and piece-parts and additionally, isometric drawings showing clearly the relationship between the various components.

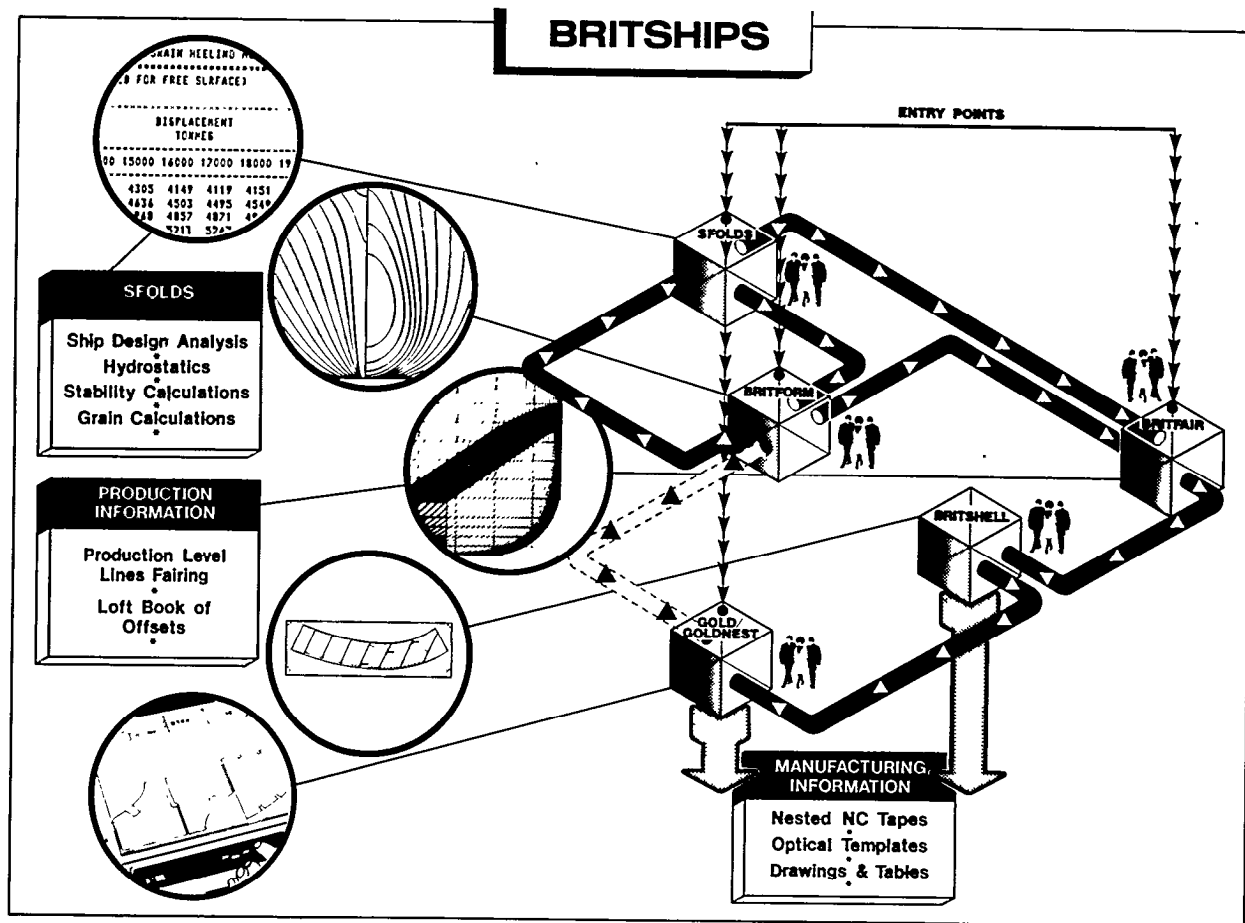


FIG.1



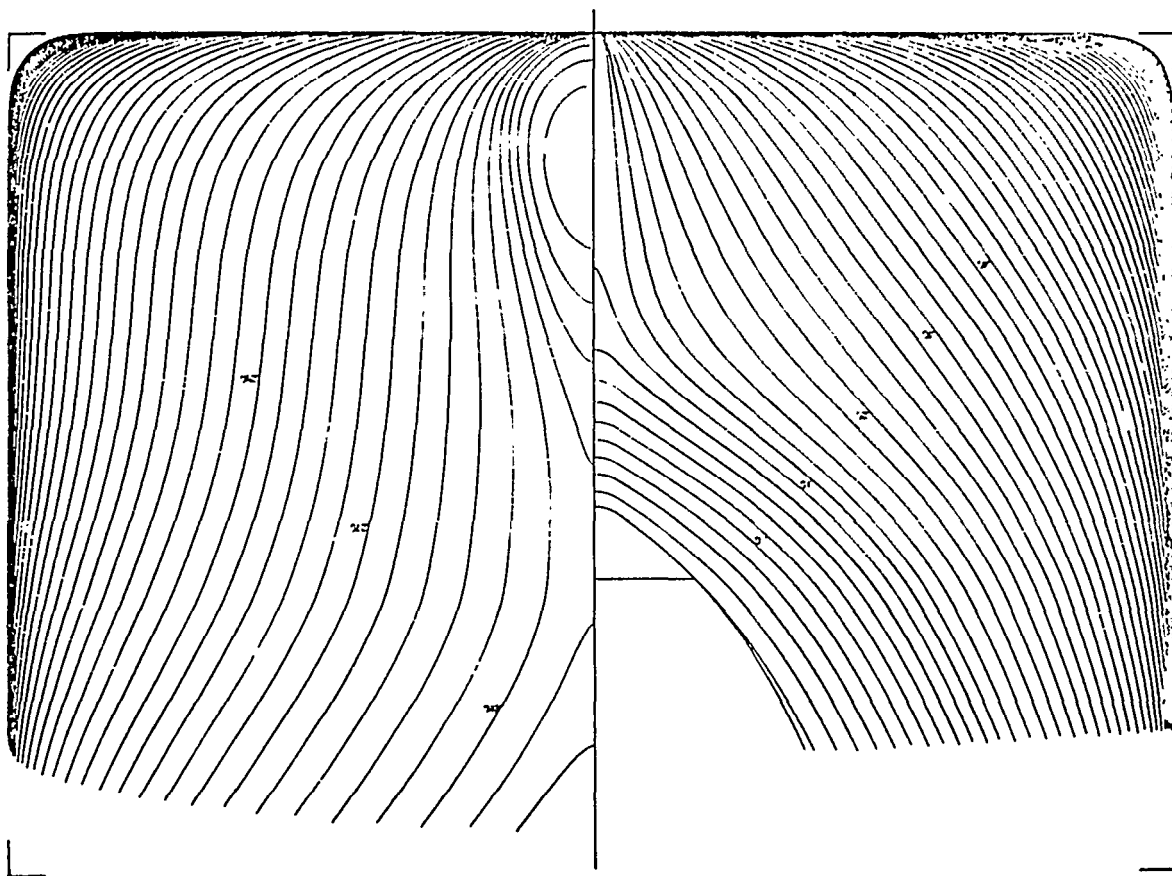


FIG.2 BUILDING FRAMES FROM BRITFORM

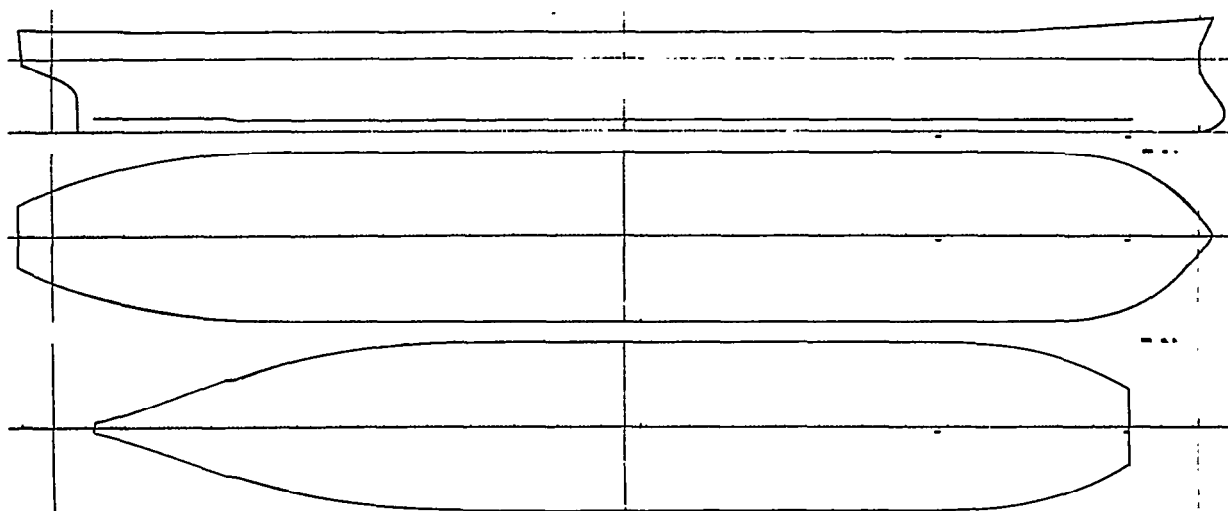


FIG. 3 OUTLINE GENERAL ARRANGEMENT

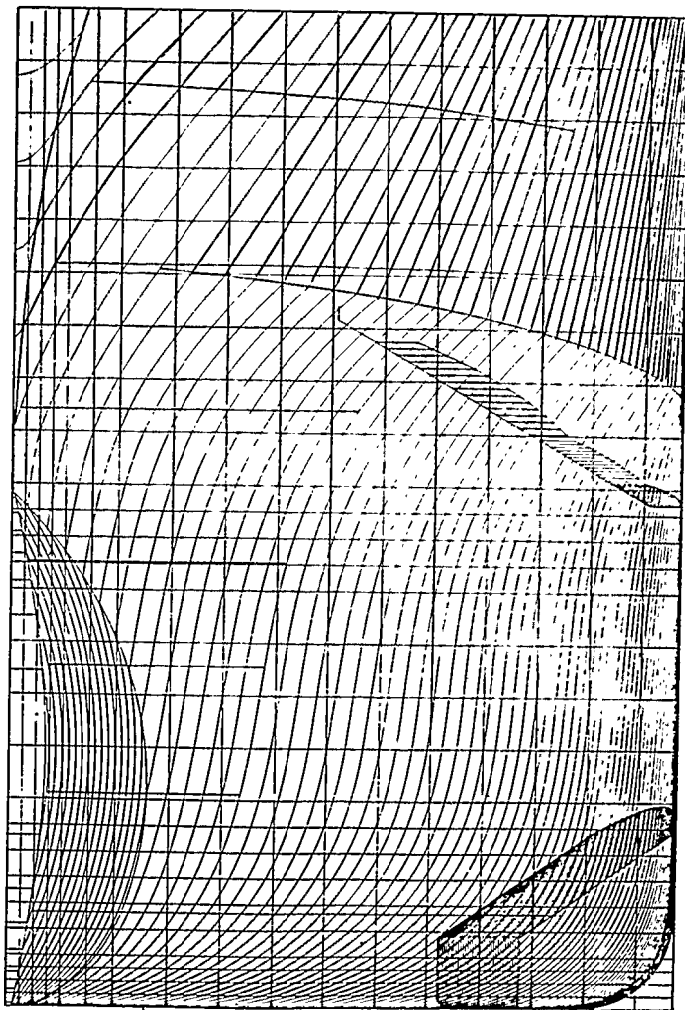


FIG.4 BRITFAIR-EXAMPLE OF BOW ENGINEERED FOR PRODUCTION

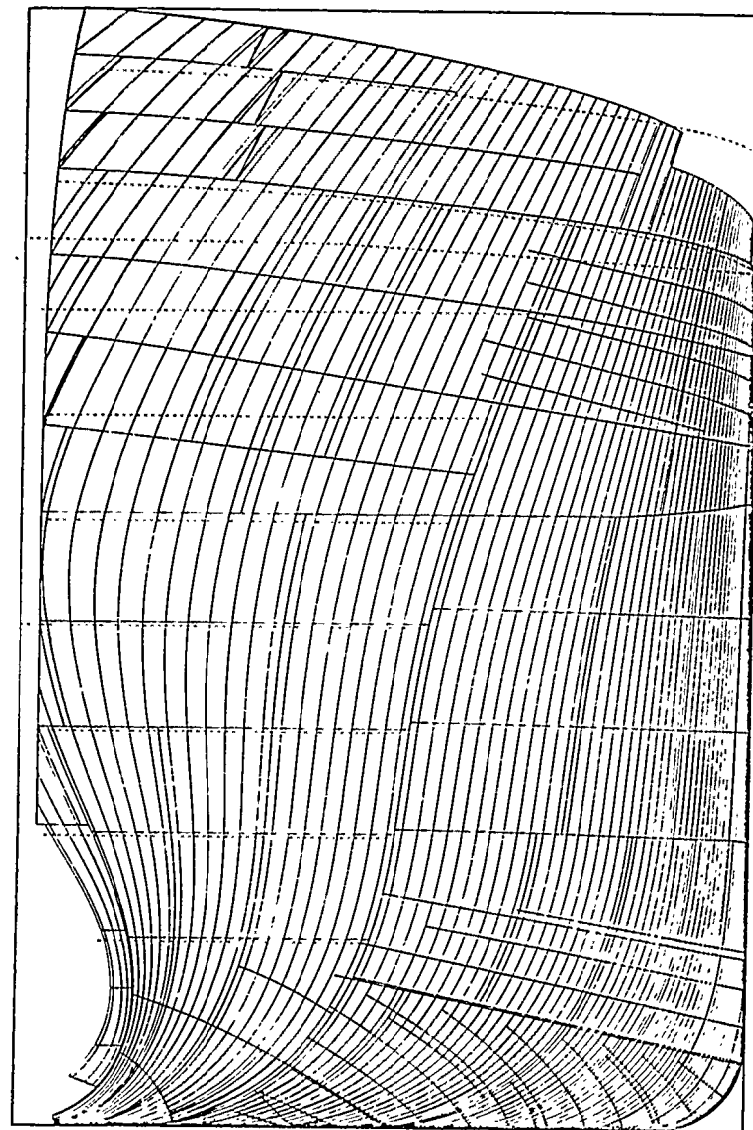


FIG.5 SHELL ARRANGEMENT LONGITUDINALS AND DECK-AT-SIDE LINES AS DEFINED IN THREE DIMENSIONS

FIG.6 CHECK DRAWING FOR DEVELOPED SHELL PLATE

BSRA No. 1/ 1	SHIP 99999	BSRA/PLATE 1
	PART	ORDERED PLATE
GRADE	0.015 M.	0.015 M.
THICKNESS		
LENGTH		4.907 M.
BREADTH		2.234 M.
AREA	8.738 SQ.M.	10.961 SQ.M.
WEIGHT	1028.935 KGS.	1290.701 KGS.
SCRAP	20.281 %	261.766 KGS.
KNUCKLE ON UPPER SEAM AT 'FRS' 1 8 8 8 8		
KNUCKLE ON LOWER SEAM AT 'FRS' 1 8 8 8 8		
PREPARATION STATISTICS		
LENGTH OF RAPID TRAVEL = 24.0M		
LENGTH OF BURN ON MAJOR HEAD = 8.6M		
LENGTH OF MARK MOTION = 5.6M		
LENGTH OF NORMAL MOTION = 3.9M		
NUMBER OF PIERCE COMMANDS = 3		
NUMBER OF POP SEQUENCES = 69		

FIG.7 PLATE PREPARATION STATISTICS

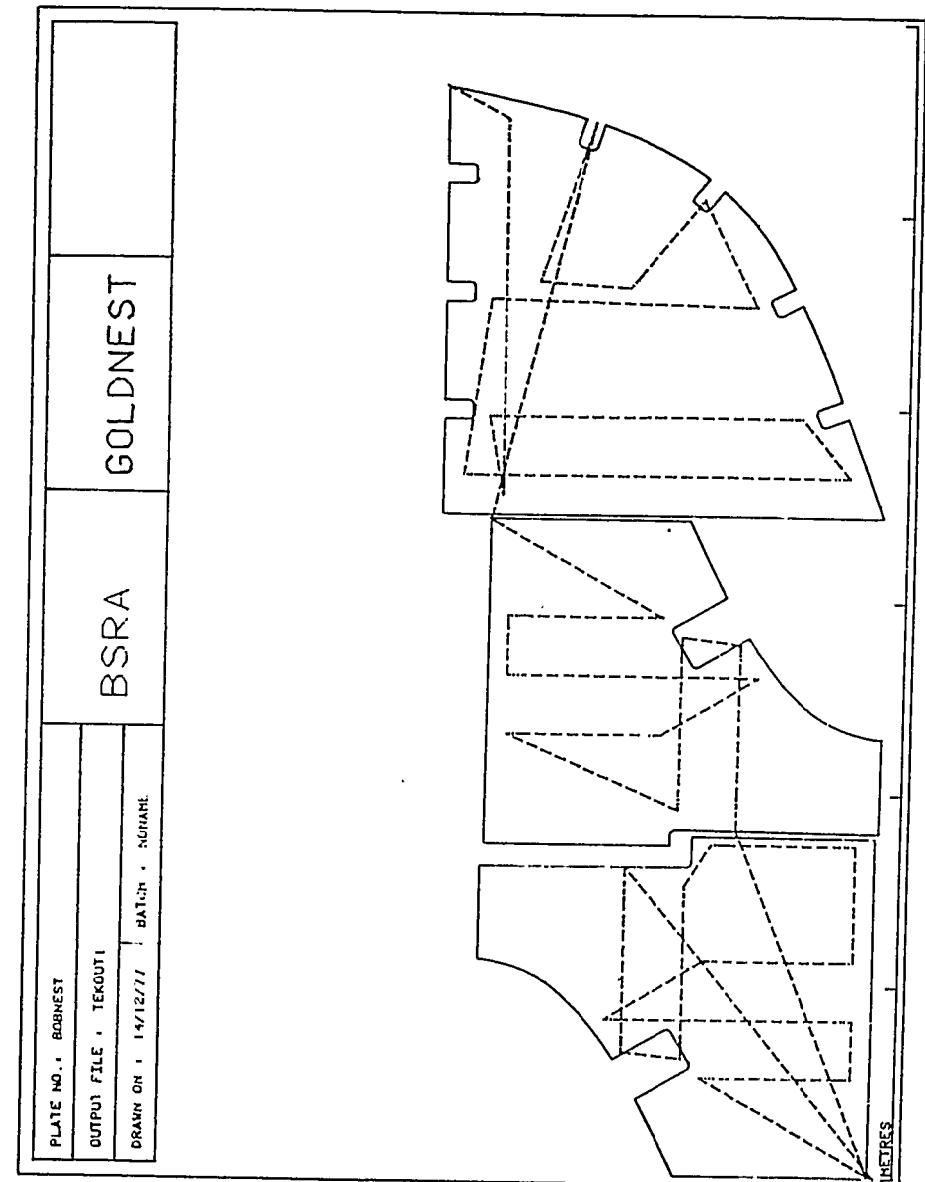


FIG.8 VERIFICATION DRAWING FOR NESTED PLATE

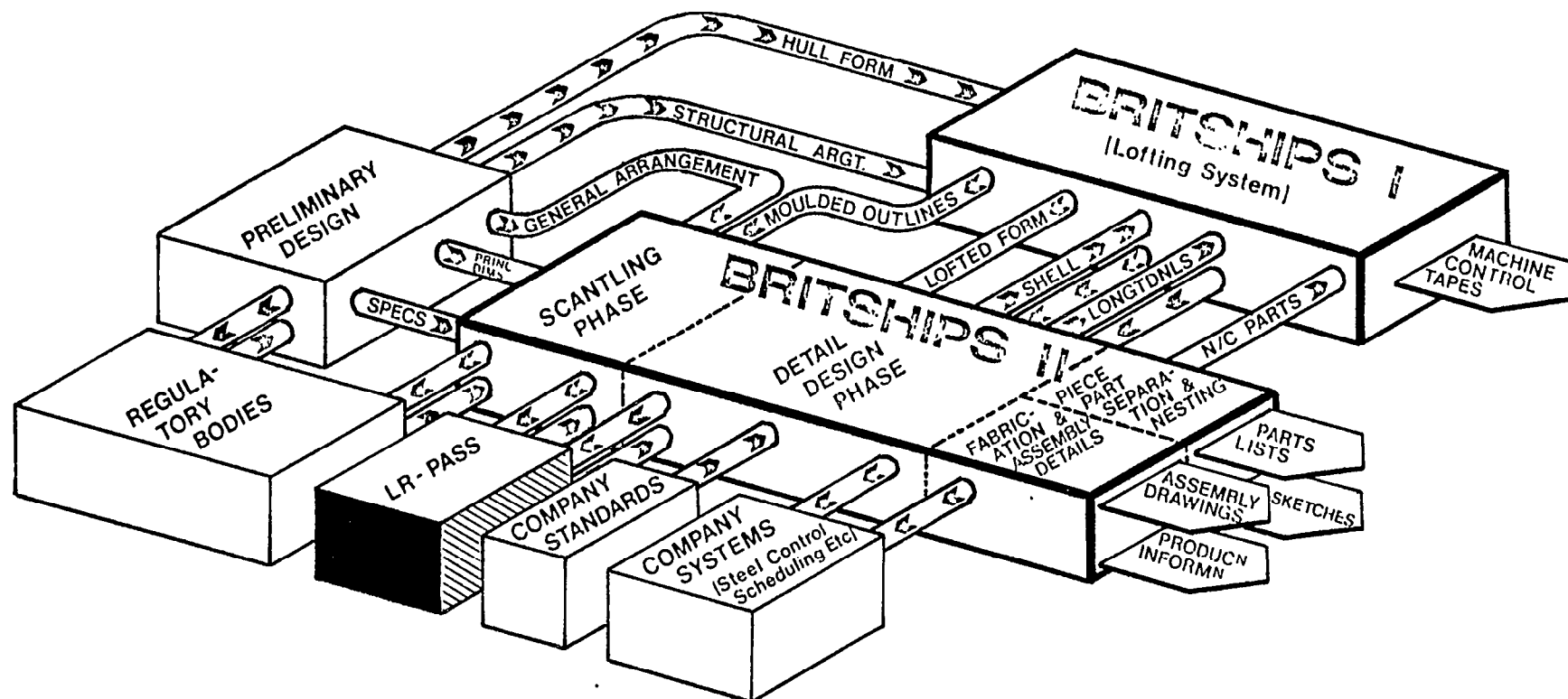


FIG. 9 BRITSHIPS II INFORMATION FLOW

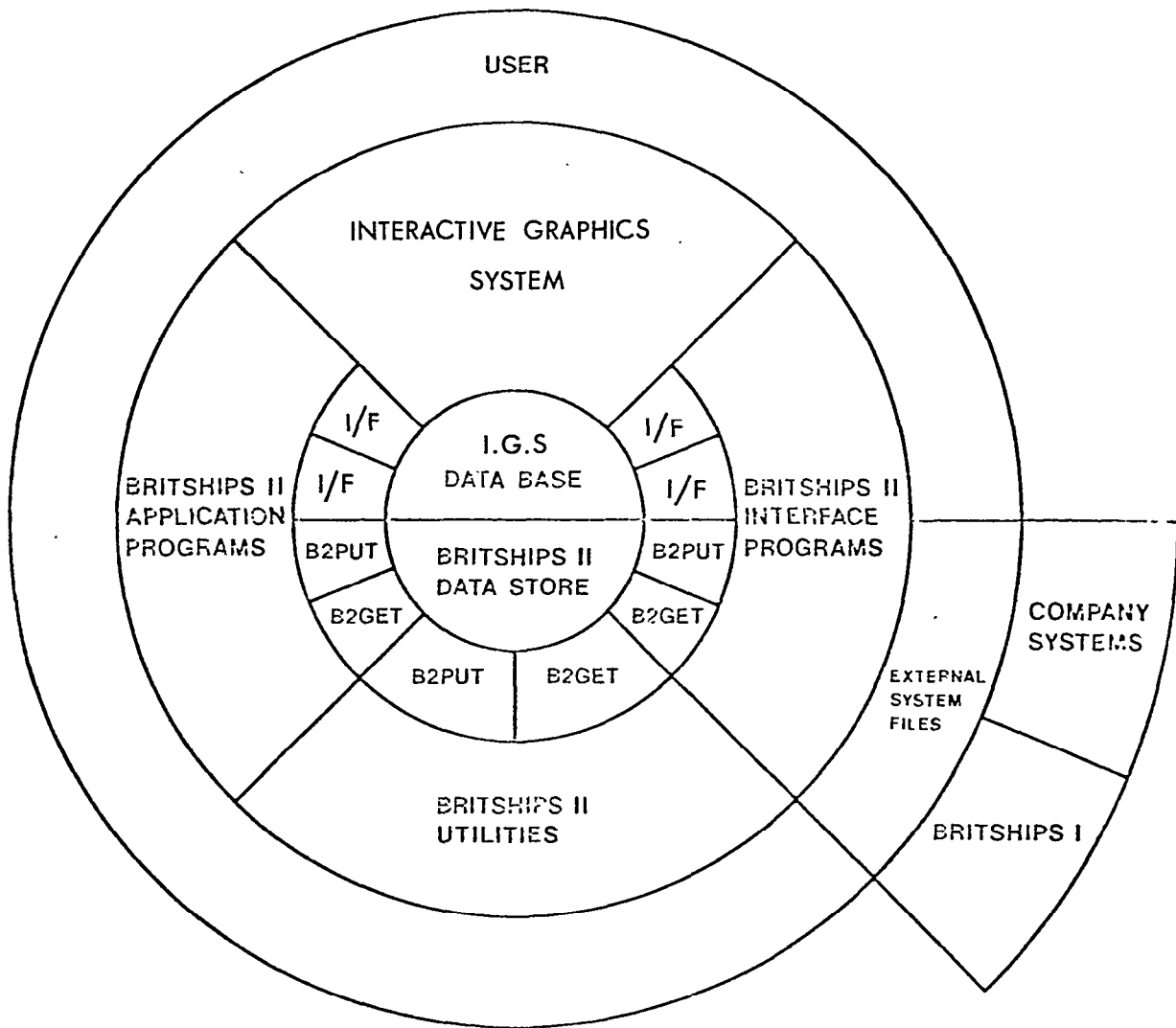


FIG. 10 BRITSHIPS II SYSTEM OVERVIEW

## DESCRIPTION OF SFOLDS PROGRAMS

ABSOLUTE PROGRAM NAME	PROGRAM NOTICE NUMBER	BRIEF DESCRIPTION
BODY	PN17	Program to compute a control tape file for an ESSI drawing machine, for drawing a complete body plan including super-structure and other appendages using the standard 23 station offset file.
BPLOT	PN25	Program to produce a rough plot of a body plan and simple portion data on the line printer or the User's terminal.
BSAD	PN60	Program to generate bending moment, shearing force and deflection curves.
COLLECT	PN57	Program to collect and generate input to TRISTA.
DAMAGE	PN56	Program to compute damage stability particulars allowing for the change in free surface in partly filled or intact compartments.
DEFORM	PN12	Program which uses the parent hull offset file data on the standard 23 stations to modify the form in order to derive a new form with specified form characteristics and principle dimensions. Four alternative methods of hull form derivation are available when using this program.
HYDRE	PN61	Program to compute trimmed hydrostatics of sectional properties.
HYTAB	PN23	Program to produce formatted tables of the hydrostatic particulars in A4 format using the output file created by the HYDRE program.
KNTAB	PN24	Program to produce formatted tables of the cross curves of statical stability in A4 format using the output file created by WSTAB.
KPORT	PN62	Program to generate simple portion data using the displacement station offsets, together with the positions of the transverse bulkheads and decks. These simple portions can be used by various other programs.

ABSOLUTE PROGRAM NAME	PROGRAM NOTICE NUMBER	BRIEF DESCRIPTION
LONSH	PN74	Program to compute launching particulars for a ship or any floating object for a series of travels down the launching ways.
MSHF	PN63	Program to create a design file from BSRA improved and revised standard series data.
MSPE	PN3	Program to estimate power requirements and calculate resistance particulars for BSRA improved and revised standard series data.
PARTS	PN5	Program to create an offset file on the 23 standard displacement stations between the 2 transverse bulkheads specified, given the offsets for up to 50 stations in the ship's length. Any simple portion data is also processed to define the ship between the transverse bulkheads specified.
TANK	PN9	Program to produce calibration tables in terms of soundings or ullages for any compartment defined by simple portion data, which may have been generated by KPORT.
SR60	PN10	Program to create a design file from the US Series 60 forms.
TRISTA	PN22	Program to calculate the trim and stability for any number of loading conditions.
WSTAB	PN54	Program to compute the cross curves of statical stability allowing for super-structures, bossings and free trim.
BALCO	PN51	Program to compute sinkage, change in trim, change in draught fwd. and aft, for up to 50 compartments on any number of conditions.
VOLUME	PN83	This program computes the volumes and centre of gravity of the holds and tanks enclosed by decks and bulkheads.
BENDS	PN37	Program to calculate longitudinal strength particulars for any number of loading conditions.



ABSOLUTE PROGRAM NAME	PROGRAM NOTICE NUMBER	BRIEF DESCRIPTION
GRAIN	PN6	Carriage of grain program for partly filled compartments of bulk carried to check compliance with SOLAS 74 requirements.
FGRAIN	PN152	Full hold grain heeling moments in accordance with the IMCO SOLAS 74 Convention.
KGCRT	PN153	Computation of critical KG values, maximum allowable deadweight moments and maximum allowable grain heeling moments.
FREEBD	PN15	Calculation of summer freeboards.
DBAL	PN67	Prediction of dBA noise levels.
APPROVE	PN151	Checks data in DESIGN or PORTN file.
OFFTAB	PN109	Tabulates DESIGN file.
FLOOD	PN7	Floodable length curve calculations.
DENSE	PN108	Increases the number of portions in a PORTN file.
OPDS	PN131	Optimum Propeller Design from TR00ST Series.

A NATIONAL COALITION FOR THE SHIPBUILDING TECHNOLOGY PROGRAM

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A B S T R A C T

An investigation of an approach to a U.S. Navy sponsored shipbuilding technology program is discussed. An approach is recommended, and a detailed project plan for a shipbuilding technology program is proposed.

## Section 1

### INTRODUCTION

The U.S. Navy has announced its intention to initiate a major program for the enhancement of shipbuilding technology in the United States. The objectives of this program are to improve the quality, cost, and construction time for future U.S. Naval Ships, and to strengthen this country's shipbuilding industrial base. This motivation is heightened by the Administration's plans to increase the Navy's fleet to 600 ships by 1988. This program is currently budgeted as a six-year, \$80M effort, though its format has not been defined.

Previously the Naval Sea Systems Command had contracted with SofTech, Inc. to assess Air Force initiatives in manufacturing technology with respect to Navy needs. Both the Navy and the Air Force have established programs to promote computer-aided manufacturing which have differed markedly in budget, in approach, and in industry involvement and acceptance. SofTech was directed to consider the applicability of the ICAM (Integrated Computer-Aided Manufacturing) Program approach to a Navy STP (Ship building Technology) Program.

This paper recommends an approach to the planning, management, and integration portion of a national, participative Shipbuilding Technology Program (STP). These recommendations are SofTech's, and are not to be construed as government policy. They are based on SofTech's initial analysis, and on pertinent comments received from individuals in the Navy and the shipbuilding industry.

## Section 2

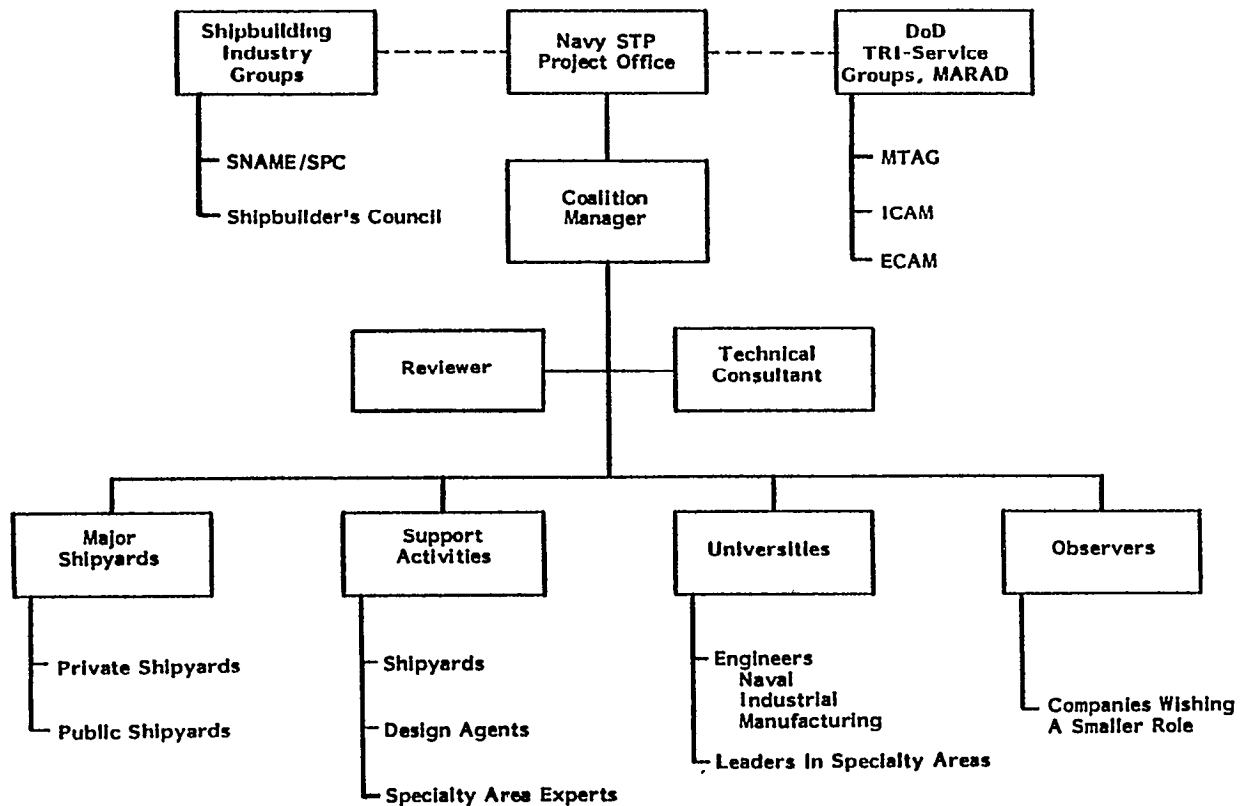
### THE ORGANIZATION: A NATIONAL COALITION

Two primary conclusions have emerged from discussion and analysis of the issues regarding the planning and management of a program of the scope of STP. First, such an undertaking cannot succeed without the acceptance and direct involvement of the Shipbuilding industry. The industry must participate in needs definition, planning, focus, and implementation of the Shipbuilding Technology Program. The immediate corollary to this is that participation of all major segments of the industry can be secured through utilization of existing standing committees and forums. These groups include the many panels of the Ship Production Committee of SNAME, the IREAPS organization, the Maritime Administration's National Ship Research Program, and others.

The second major conclusion drawn with respect to developing a format for STP is that the organizational and technical concepts followed by the ICAM program represent an excellent model. This is true because the coalition concept has proven useful in effecting direct participation of diverse industry groups with the government, and because past technical results have been well received and implemented by government and industry participants.

For the above reasons, a national shipbuilding industry coalition is recommended as the most appropriate organizational concept for the planning and integration of the STP. The schematic of Figure 1 shows the relationships among the various players.

STP Coalition members have the following recommended functional roles. A Navy project office would be established to provide guidance and oversight for the planning and integration coalition activities, and to participate in the planning process. The project office would receive advice from Shipbuilding industry groups such as the Ship Production Committee of SNAME and the Shipbuilder's Council of America, and would maintain liaison with major DOD-level activities such as the Manufacturing Technology Advisory Group.



**Figure 1. Recommended STP Planning and Integration Coalition**

The Coalition Manager would serve as a prime contractor for the national coalition, and would have contractual responsibility for program deliverables (i.e., STP Master Plan). The Coalition Manager is essentially the systems engineer for the planning effort and would serve as the project consultant in the application and integration of CAM technology. This role also would include all required training in analytical techniques and integration methods.

The Technical Consultant would provide a broad baseline of shipbuilding knowledge, from both government and commercial perspectives. The TC would lead shipbuilding technology analyses to identify candidate STP projects, and would develop return on investment analyses for these.

The Reviewer would focus the planning efforts of the coalition by reviewing and approving the STP Master Plan and the priorities for candidate STP projects. This role, which might possibly be filled by a standing organization such as IREAPS or the Ship Production Committee, would also include steering the evolution of the planning and integration coalition itself.

Major Shipyards would participate by recommending projects for consideration, leading designated shipbuilding process analyses, and by reviewing similar analyses prepared by other yards. The yards would recommend priorities for STP projects, and provide data for ROI analyses.

Support Activities which would include design agents, specialty consultants, and possibly additional shipyards, would provide specialty area expertise or concentrate on the analysis of identified STP projects. Universities would provide future perspective to the coalition's activities, and the Observer role will be maintained for those organizations desiring a lesser role but wishing to remain informed.

The primary goal in selection of coalition members is the inclusion of a sufficiently diverse group so that all shipbuilding areas are covered. Ship builders must be included to ensure that changes considered are practical and feasible. Shipbuilding consultants and ship design agents must be included to provide specialized technical knowledge, objective judgement, and broad industry perspective. Universities and affiliates should be included to provide a future-oriented perspective, and knowledge of advancing state-of-the-art technology.

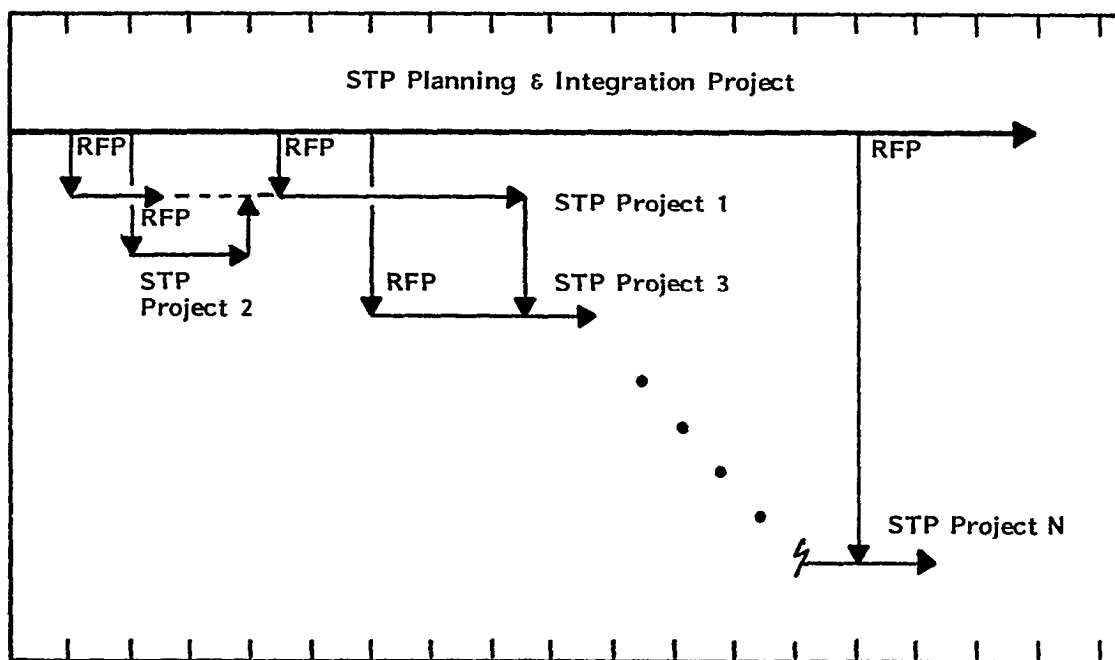
The impact of each organization on Navy procurements should be evaluated when selecting coalition members. STP must represent both Navy and commercial ship building views, since it is unreasonable to separate one from the other. However, the coalition must show a major involvement in Navy shipbuilding to ensure that STP results will have the desired effect on future Navy costs and readiness, and on industry responsiveness to Navy needs.

A final, key attribute for coalition membership is the attitude of organizations and individuals toward change. A proven, progressive attitude toward change is essential to STP Success, evidenced both by a willingness to share company data (on a controlled basis), and a willingness-to work toward the good of the industry, not only individual company interests.

### Section 3

#### THE APPROACH: SYSTEMS ENGINEERING

The relationship of the STP planning and integration project, which this paper describes, to the total STP program is shown in Figure 2. It is recommended that the planning and integration effort be maintained throughout the life of the STP, so that the STP Master Plan can serve as the planning "road map" and baseline for integration of the ongoing specific STP projects.



**Figure 2. Recommended Shipbuilding Technology Program**

The above figure highlights the key benefit of the technical approach advocated in this paper: integration. The disciplined systems engineering methods described here provide the basis for integrating the development of individual STP projects in such a way that they interact smoothly with each other and with existing systems. It is this integration which will provide the substantial improvements in productivity which are the goal of the Shipbuilding Technology Program.



Figure 3 presents a functional approach to developing the Shipbuilding Technology Program. The STP planning and integration project described in this paper is concerned with Boxes 1 and 2 of this figure.

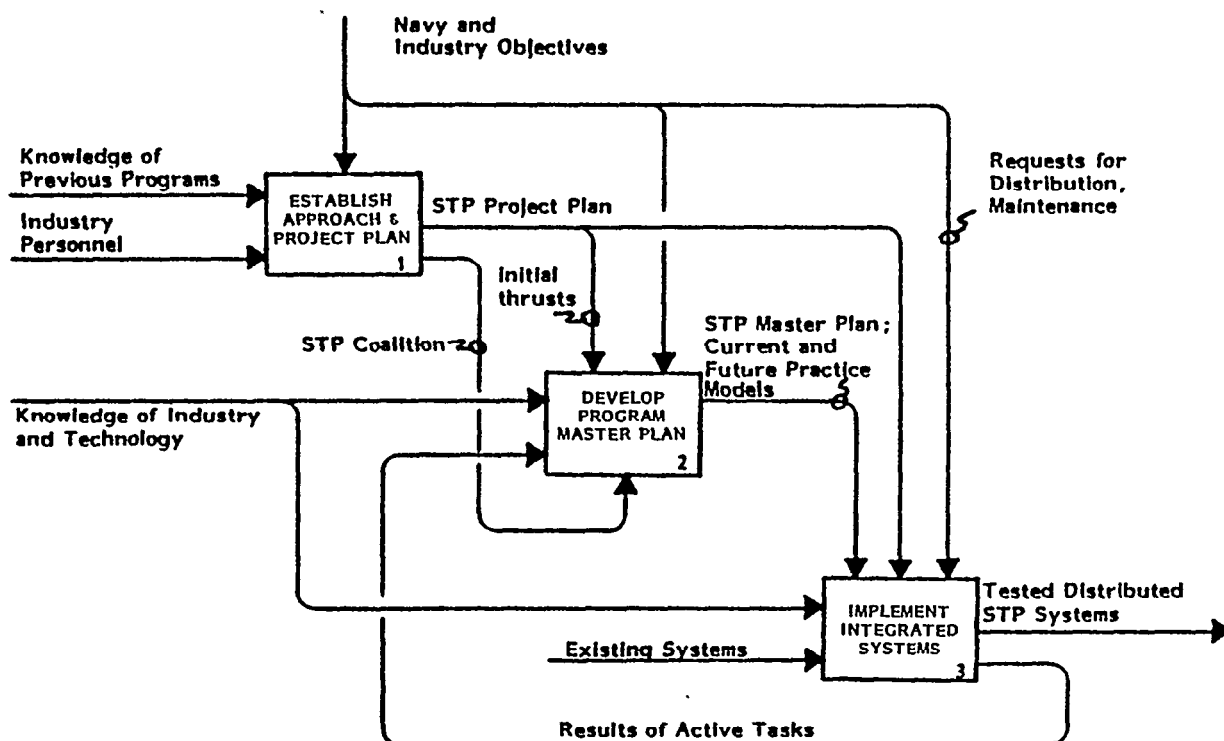


Figure 3. Develop Shipbuilding Technology Program

First, an approach and project plan must be established, to document the scope, approach, organization, and methods for STP planning and integration. This paper summarizes a first cut at a project plan. Key inputs are industry personnel and knowledge of previous programs, such as the Navy's Computer Aided Structural Detailing of Ships (CASDOS), Computer Aided Ship Design and Construction (CASDAC), and MarAd's Research and Engineering for Automation and Productivity in Shipbuilding (REAPS). This activity, driven by both Navy and industry needs, will result in an STP Project Plan, complete with budgets and schedules, and a defined (and contracted) national STP industry coalition.

The purpose of the STP Coalition is the creation and maintenance of the Master Plan for STP. The creation of the Master Plan will be guided by Navy and industry needs, as well as near-term, high-payoff initial thrusts identified during early project planning. Starting points for these initial thrusts include ongoing IREAPS projects, U.S. Navy Advanced Technology and Manufacturing Technology projects, as well as each yard's existing backlog of modernization projects. Knowledge of the shipbuilding industry and of available technology will be the primary input to this planning. Once the STP has been established, continuous inputs regarding active tasks will also impact planning. The major output of this phase will be models of current and future shipbuilding practice, and the STP Master Plan. The Master Plan will define and sequence the tasks required to move the shipbuilding industry from current to future shipbuilding practice. The Navy and industry will work together to determine the scope and priority of all STP modernization projects.

The final phase of the Shipbuilding Technology Program will be the implementation of the integrated STP systems, in accordance with the STP Project Plan and the STP Master Plan. The STP systems will be tested thoroughly, and distributed in response to industry requests. The implementation work will be performed by members of the shipbuilding industry. System development may be accomplished by small coalitions, and these efforts will be distinct from those of the STP planning coalition. Existing systems and proven technology will be utilized where possible to minimize technical risk. These systems will be applied in concert with the industrial knowledge base to develop and integrate fully functional STP systems into ongoing shipyard operations.

Further detail is provided here concerning the development of the STP Master Plan (Figure 4). Guided by the STP Project Plan, the current industrial practice of U.S. Shipyards would be documented, based on the knowledge of the industry and pertaining technology possessed by the STP coalition.

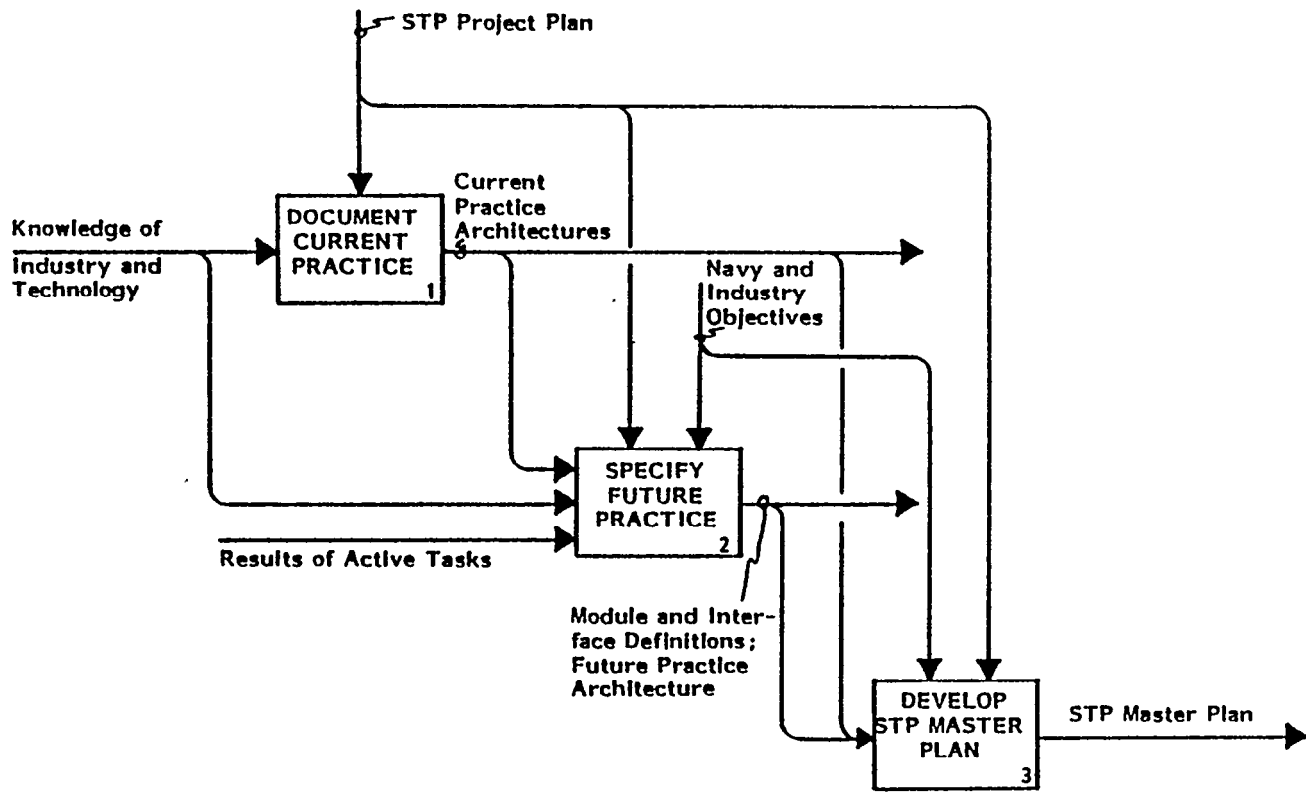


Figure 4. Develop Program Master Plan

The current shipbuilding practice model and the coalition's knowledge base would then be utilized to develop a model documenting future shipbuilding practice. This procedure would be guided by the STP Project Plan and defined Navy and industry objectives. The products of this procedure will be the future shipbuilding practice model, and interface definitions for proposed STP systems.

The information produced during these two activities would be the primary input to developing the STP Master Plan. This plan defines a roadmap displaying the priority and interdependencies of all STP systems and projects. The priority of these projects is determined jointly by the Navy and the shipbuilding industry, with the advice of the Reviewer.

The models developed in the course of the first two activities shown on Figure 4 will be built according the the strategy shown in Figure 5.

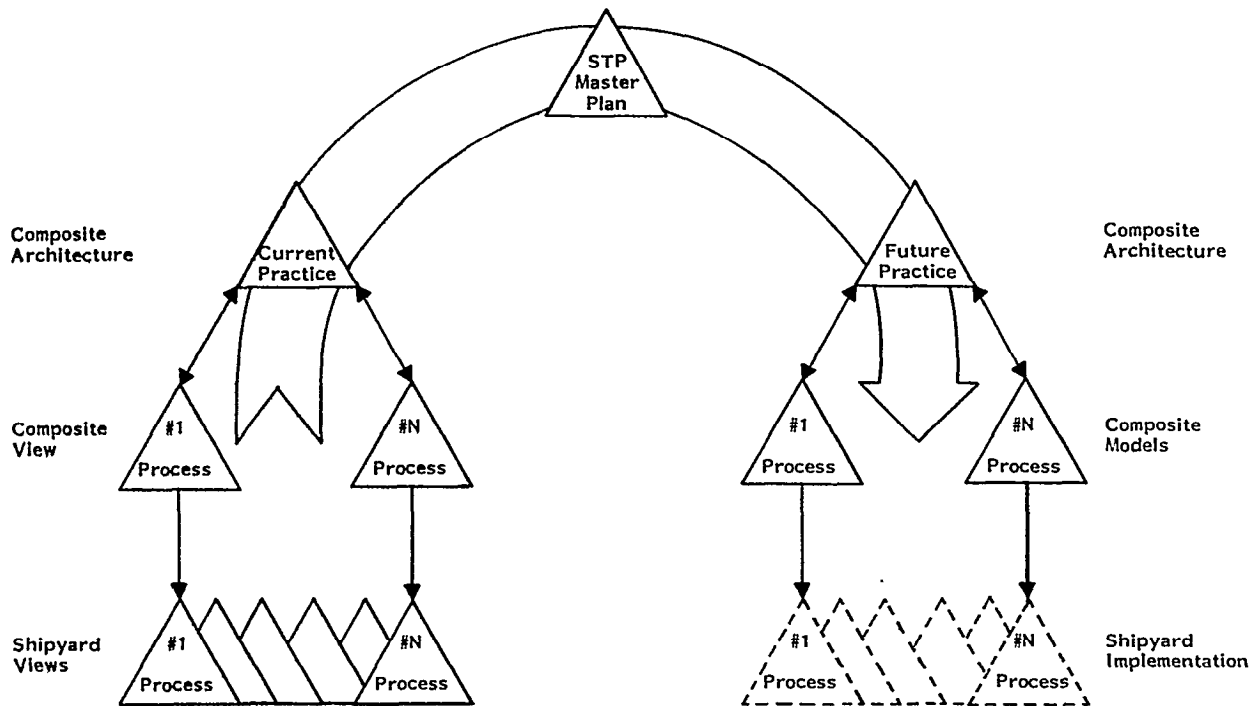


Figure 5. Models Used for STP Master Planning

The STP effort will identify potential improvements by building a model of current shipbuilding practice and model of possible future practice, then defining and sequencing projects to move from current to future practice.

The model of ship design and construction should be developed on a three tier structure. One begins first with a "current practice" shipyard view. This model of construction is peculiar to each shipbuilder and construction process. For each process, a single Major Shipyard should be responsible for developing its company's "Current Practice" Shipyard View; this Shipyard and the

Coalition Manager should then lead two to three other Major Shipyards in augmenting this model with their shipyard viewpoints. An aggregate representation of all that is required to design, engineer, construct, and maintain that shipbuilding process would emerge; this aggregate representation would be the process's "Current Practice" Composite View.

An important consideration in the development of composite models is that of security of data viewed as proprietary by coalition members. It is recommended that the following security system be required in all coalition' subcontracts. All information submitted to the Coalition Manager must be stamped with security level, indicating that it may be disclosed only to the Coalition Manager, only to the Manager and the government, or to all coalition members.

The coalition would develop "Current Practice" Shipyard and Composite Views for each of the many shipbuilding processes. Once all selected Composite Views are developed, a careful analysis would be made of their underlying common structure. This structure represents the third tier of ship design and construction, and is defined via a "Current Practice" Composite Architecture. The Composite Architecture describes all of the underlying of Common construction functions found in the process models. Making use of the "Current Practice" Composite Architecture, and by analyzing emerging technologies and planned improvements, a "Future Practice" view of ship design and construction would be developed. This future would be represented by both individual "Future Practice" process models, and by a common "Future Practice" Composite Architecture, as shown.

The time frame for implementation of the STP planning and integration effort is crucial, so that needed productivity improvements can be realized as soon as possible. The integration of ongoing and planned manufacturing technology efforts, as well as the identification of new STP projects should, if begun immediately, significantly enhance the industry's capabilities with respect to the Navy's 600 ship requirement.

The development of the STP Master Plan can and should begin immediately. Within 6 to 12 months, technical modernization projects could begin. These projects, which are yard and/or procurement specific, feature generally well-defined problems, speedy implementation, and short payback periods. More generic technology applications, which might apply to more than one facility and require cooperative planning and execution, could be undertaken in one to three years. Finally, support technology and systems, integrated across the industry, could get under way in the four to six year time frame.

#### Section 4

### TOOLS AND TECHNIQUES

Because the approach recommended here for the planning and integration of the Shipbuilding Technology Program represents a systems analysis task of almost unprecedented size, special tools and techniques are required to assist in planning, analysis, and communication. A rigorous language is required, to provide for unambiguous communication among the many diverse groups who will perform on STP. A method of structured analysis which provides a means of controlled decomposition to permit attacking problems in parallel as opposed to in series, is required. Finally, a proven integration methodology is required, to provide for clean interfaces and clear divisions among sub-problems so that sub-problem solutions can be assembled into working systems.

To meet these needs, SofTech has recommended the use of the ICAM Definition (IDEF<sub>0</sub>) Language. IDEF<sub>0</sub> is in the Public Domain, and complete literature and courses have been developed, and are available. Additionally, the following organizations have adopted IDEF<sub>0</sub> as their standard language for use in describing and analyzing CAD/CAM systems:

- 0 Air Force Manufacturing Technology, ICAM
- 0 Army ECAM
- 0 Society of Manufacturing Engineers
- 0 Computer-Aided Manufacturing-International
- 0 DoD Manufacturing Technology Advisory Group (Recommended)

## Section 5

### CONCLUSIONS AND RECOMMENDATIONS

These conclusions are based upon discussions concerning the approach to the planning and integration of the Shipbuilding Technology Program presented here. These discussions have been held with individuals from the shipbuilding industry and from the Navy.

With respect to scope, it is recommended that STP address the entire spectrum of shipbuilding technology, as opposed to focusing on one specific technology area, such as CAD/CAM technology.

It is anticipated that the opportunities for productivity improvement will exceed the limits of available resources. Resource limitations will be realized in capital availability, capital equipment availability, and, most critically, in the availability of capable, knowledgeable personnel to implement and use the projected systems.

The near-term emphasis of the Shipbuilding Technology Program should be placed on the selection and implementation of known critical technology areas existing in shipyards today. This work could be planned and executed in parallel with the documentation of current practice, in order to maintain the long-term benefits of integration. Technology areas for this immediate action might be selected from sources such as ongoing IREAPS projects, USN Advanced Technology and Manufacturing Technology projects, and the Marine Equipment Leasing, Inc. Technology Survey of U.S. Shipyards. This type of timely and definitive Navy action would serve to establish valuable credibility with the industry, and thus solidify industry support for STP.

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2. Maritime Transportation Research Board, National Research Council, National Academy of Sciences, "Innovation in the Maritime Industry," Office of Naval Research, Department of the Navy Contract N00014-75-C-0711, October 1979.
3. SofTech, Inc., "Integrated Computer-Aided Manufacturing (ICAM) Task I - Final Report Manufacturing Architecture" Air Force Materials Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base. Contract F33615-77-C-5012. Report No. AFML-TR-78-148, November 1978.
4. SofTech, Inc., "CASDAC Analysis Final Report." Naval Sea Systems Command Code 63R2, Washington, D.C. Contract F33615-79-C-5157. SofTech Report No. 2096-2, May 1981.
5. SofTech, Inc., "Function Modeling Manual - IDEF<sub>0</sub>," Materials Laboratory, Air Force Wright Aeronautical Laboratories, Wright-Patterson Air Force Base, Report AFWAL-TR-81-4023, Volume IV, June, 1981.
6. "Standards for Computer-Aided Manufacturing January 1977 Final Technical Report." Manufacturing Technology Division, Air Force Materials Laboratory, Wright Patterson Air Force Base, Report No. AFML-TR-77-145, December 1977.

## **I N T R O D U C T I O N**

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<b>WHAT</b>	<b>IMPROVE PRODUCTIVITY</b>
<b>WHY</b>	<b>BETTER SHIPS FASTER AND CHEAPER</b>
<b>WHERE</b>	<b>U. S. SHIPBUILDING INDUSTRY</b>
<b>HOW</b>	<b>INTEGRATED TECHNOLOGY</b>
<b>WHO</b>	<b>NATIONAL COALITION</b>
<b>WHEN</b>	<b>IMMEDIATELY</b>
<b>HOW MUCH</b>	<b>SCOPE AND RESOURCES</b>



# SHIPBUILDING TECHNOLOGY PROGRAM

## WHAT: IMPROVE PRODUCTIVITY

- IMPROVED PROCESSES, METHODS, EQUIPMENT
- MAXIMUM DISSEMINATION OF RESULTS
- STIMULATE INDUSTRY INVESTMENT

## WHY: BETTER SHIPS FASTER AND CHEAPER

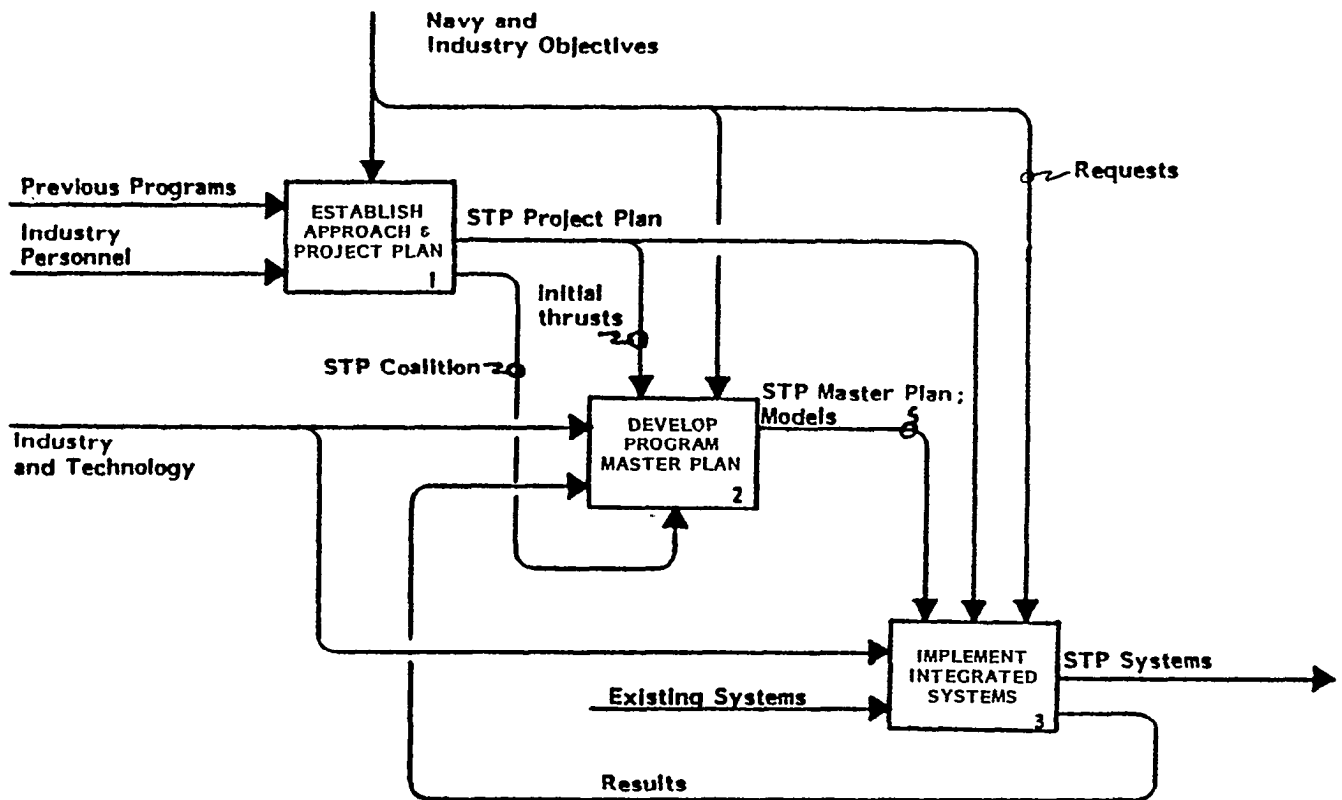
- REDUCE ACQUISITION TIME
- IMPROVE AS-BUILT QUALITY
- REDUCE LIFE-CYCLE COSTS

## WHERE: U.S. SHIPBUILDING INDUSTRY

FUNCTION	SECTOR	
	PRIVATE	PUBLIC
DESIGN	✓	✓
CONSTRUCTION	✓	
MAINTENANCE	✓	✓
REPAIR & OVERHAUL	✓	✓

## HOW: INFUSION OF INTEGRATED TECHNOLOGY

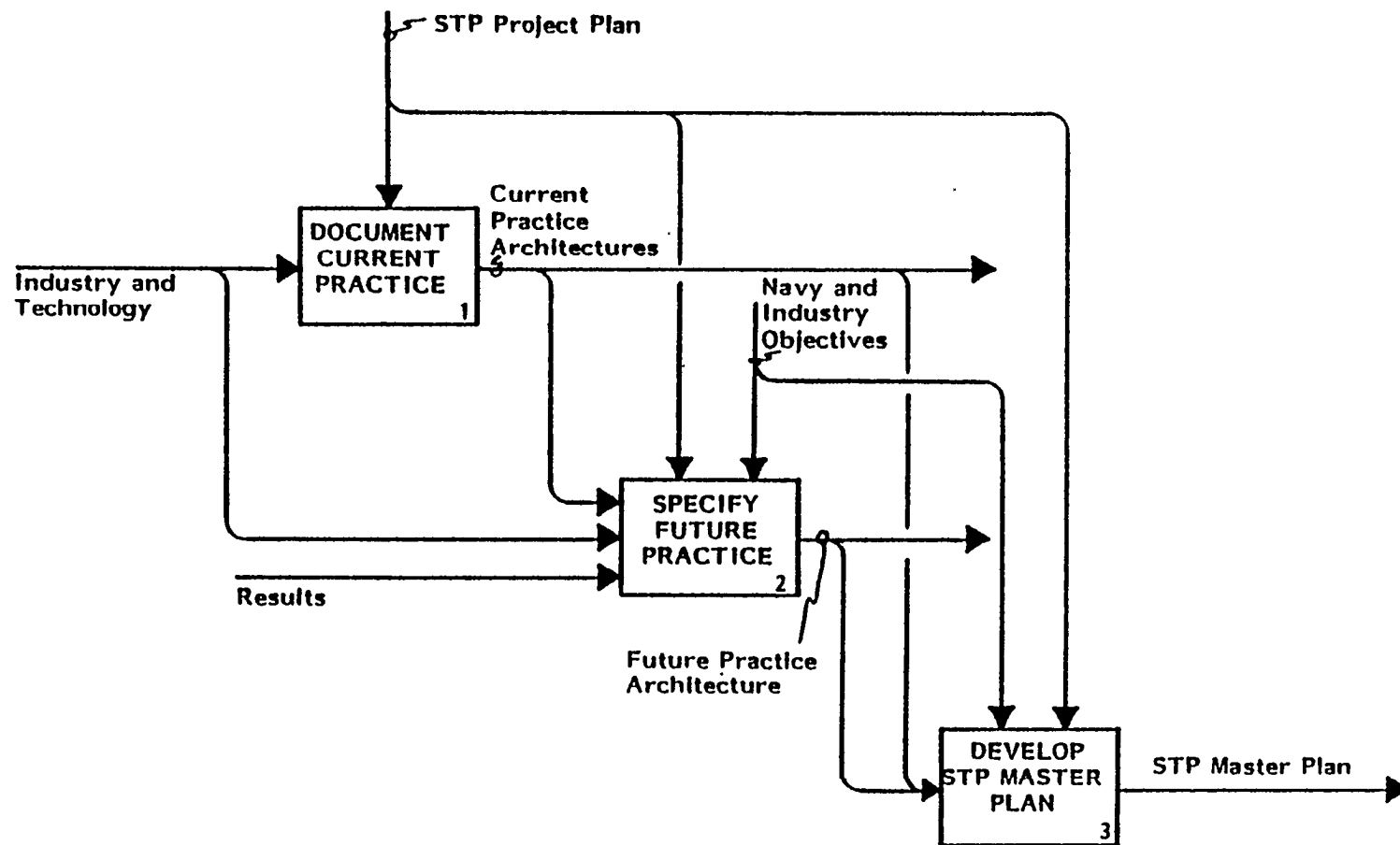
ORGANIZATIONAL APPROACH	NATIONAL COALITION
TECHNICAL APPROACH	SYSTEMS ENGINEERING
TOOLS AND TECHNIQUES	FUNCTIONAL ANALYSIS



DEVELOP SHIPBUILDING TECHNOLOGY PROGRAM

# SHIPBUILDING TECHNOLOGY PROGRAM

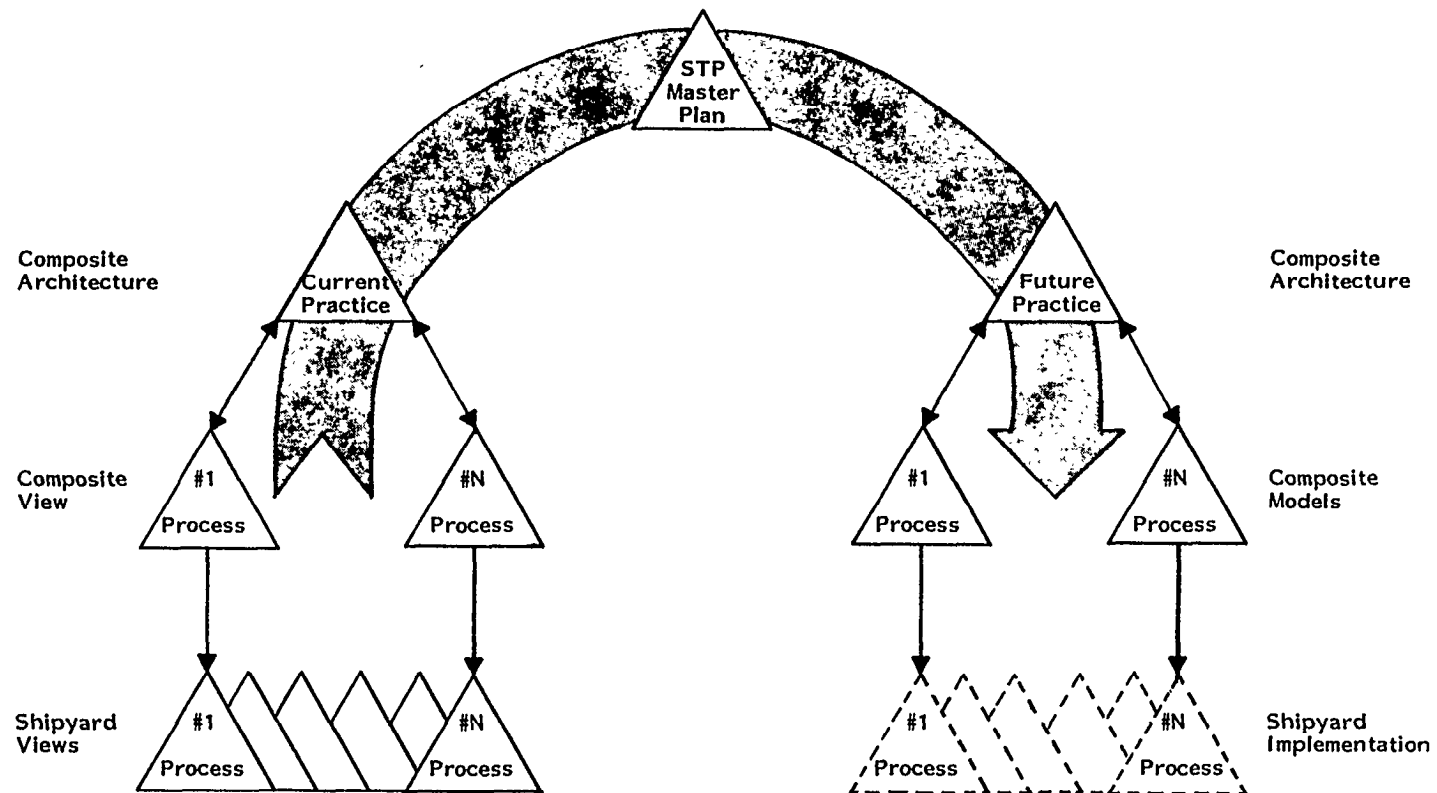
## HOW: INFUSION OF INTEGRATED TECHNOLOGY



DEVELOP PROGRAM MASTER PLAN

# SHIPBUILDING TECHNOLOGY PROGRAM

## HOW: INFUSION OF INTEGRATED TECHNOLOGY



MODELS USED IN STP MASTER PLANNING

# HOW: INFUSION OF INTEGRATED TECHNOLOGY

## MASTER PLAN OUTLINE

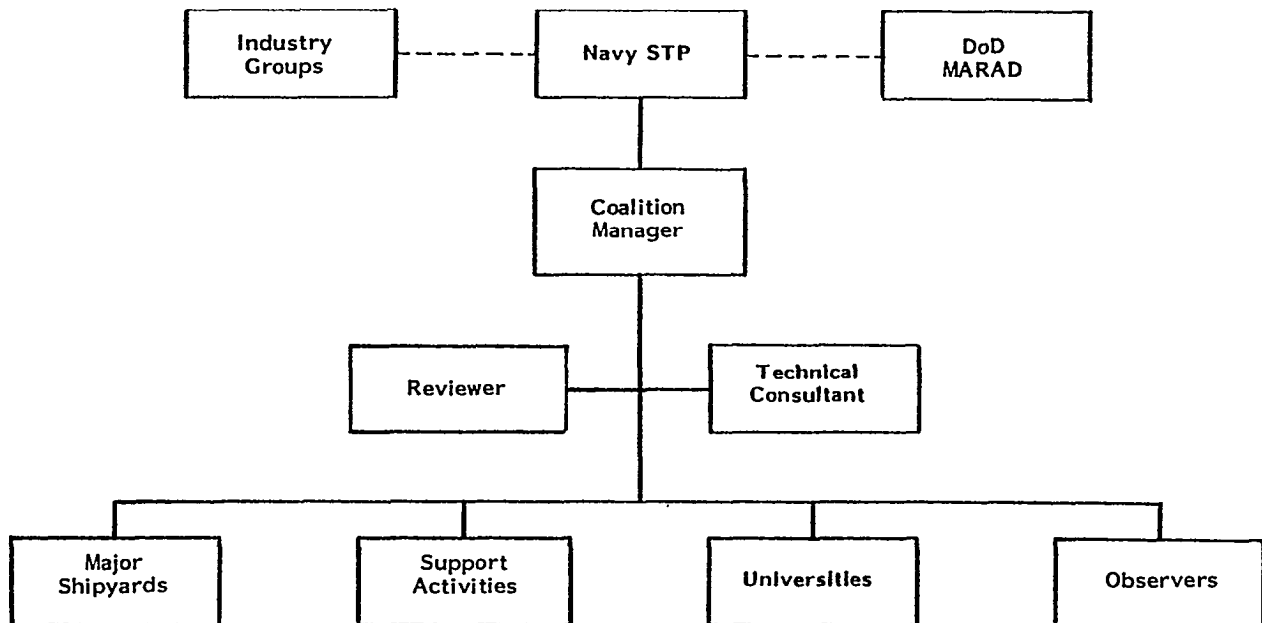
- MASTER SCHEDULE
- GUIDELINES AND STANDARDS
- FUTURE PROJECTS
  - PRIORITY
  - INTERDEPENDENCE
- INDIVIDUAL PROJECT DESCRIPTIONS

TOOLS AND TECHNIQUES	
RIGOROUS LANGUAGE	UNAMBIGUOUS COMMUNICATION
STRUCTURED ANALYSIS	CONTROLLED DECOMPOSITION
INTEGRATION METHODOLOGY	CLEAN INTERFACES

## IDEF<sub>0</sub>

- PUBLIC DOMAIN
- COURSES, LITERATURE
- STANDARD FOR
  - AF MAN/TECH, ICAM
  - ARMY ECAM
  - DoD MTAG
  - SME
  - CAM-I

## WHO: NATIONAL COALITION



COALITION ROLES	
COALITION MANAGER	STP MASTER PLAN
TECHNICAL CONSULTANT	BROAD SHIPBUILDING KNOWLEDGE
REVIEWER	SET PRIORITIES
MAJOR SHIPYARDS	DEFINE PROCESSES
SUPPORT ACTIVITIES	SPECIAL EXPERTISE
UNIVERSITIES	FUTURE PERSPECTIVE
OBSERVERS	FORUM

## WHO: NATIONAL COALITION

### MEMBERSHIP CRITERIA

- KNOWLEDGE BASE
- INDUSTRY-WIDE PERSPECTIVE
- SPECIAL VIEWPOINTS
- IMPACT ON NAVY PROCUREMENTS
- ATTITUDE: CHANGE; SHARE DATA

## WHEN: IMMEDIATELY

### TIME FRAME

NOW	• STP MASTER PLAN
6-12 mos.	• TECHNICAL MODERNIZATION PROJECTS
1-3 yrs.	• GENERIC TECHNOLOGY APPLICATIONS
4-6 yrs.	• SUPPORT TECHNOLOGY AND SYSTEMS

H O W   M U C H   :   S C O P E   A N D  
R E S O U R C E S

R E S O U R C E   L I M I T A T I O N S	
G O V E R N M E N T   F U N D I N G	P A Y   B A C K   O P P O R T U N I T I E S
C A P I T A L	P A Y   B A C K   O P P O R T U N I T I E S
C A P I T A L   E Q U I P M E N T	L E A D   T I M E S
P E R S O N N E L	S O U R C E S ,   T R A I N I N G

S U M M A T I O N

S H I P B U I L D I N G   T E C H N O L O G Y   P R O G R A M

W H A T :                    I M P R O V E   P R O D U C T I V I T Y

W H Y :                    B E T T E R   S H I P S   F A S T E R   A N D   C H E A P E R

W H E R E :                S H I P B U I L D I N G   I N D U S T R Y

H O W :                    I N T E G R A T E D   T E C H N O L O G Y

W H O :                    N A T I O N A L   C O A L I T I O N

W H E N :                I M M E D I A T E L Y

H O W   M U C H :        P A C E D   B Y   R E S O U R C E S



## **S U M M A T I O N**

### **STP MASTER PLAN**

**WHAT :** ROAD MAP FOR STP

**WHY:** BASELINE FOR INTEGRATION

**WHERE :** U. S. SHIPBUILDING INDUSTRY

**HOW:** SYSTEMS ENGINEERING

**WHO:** NATIONAL COALITION

**WHEN:** IMMEDIATELY

**HOW MUCH:** NEAR TERM VS. LONG TERM NEEDS

### **STP PROJECTS**

**WHAT:** IMPLEMENT PROJECTS

**WHY:** ACCOMPLISH IMPROVEMENTS

**WHERE:**

- BOARD ROOMS
- SHIPYARDS
- DESIGN OFFICES

**WHO :**

- USERS

**HOW:** STRUCTURED APPROACH PER MP

**WHEN:** TIME- PHASED

**HOW MUCH:** CAPITAL LIMITED, PEOPLE LIMITED

## ECONOMIC BENEFITS AND TECHNOLOGY OF CU/NI SHIP HULL SHEATHING

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### ABSTRACT

Fuel consumption of ships is related to hull roughness. The increasing high cost of fuel is the driving force behind the efforts that are expended in looking for methods which would reduce hull roughness and would maintain a smooth hull surface profile during the designed life of a ship. One such desirable method involves the use of copper-nickel.

This study examined a number of methodologies for applying Cu/Ni in sheet form. The welding of Cu/Ni clad steel was also evaluated in a shipyard environment. The cost differential between Cu/Ni sheathed and conventional painted hulls was determined for a large container ship.

The economic analysis was based on 1980 cost figures and a specific application method of Cu/Ni hull sheathing. The results were 33.5% for the effective discounted cash rate of return and 4.2 years for the zero-interest breakeven point, against an initial incremental investment of \$3.4 million using 46% tax rate.

## I. INTRODUCTION

The single most expensive aspect of operating a ship today is the cost of fuel (1). Effective energy-saving measures, in the context of the overall U. S. shipbuilding industry, would have a significant and favorable impact on the balance of payment of the Administration as well.

The fuel consumption of a conventional painted ship is strongly dependent upon the hull surface roughness. In this regard, the most important factors include the roughness of the paint, roughness induced by marine biofouling and erosion-corrosion of the steel plate. There are in the normal state-of-the-art quite a few known methodologies for controlling - to varying degrees of success to be sure - the deterioration of materials or structures exposed to marine environments. They may be classified as barriers, inhibitors, inert materials, temperature and velocity controls. A common barrier type approach for ship hulls is the antifouling coating. These coatings owe their enhanced biofouling resistance to the presence of cuprous oxide and tributyl tin oxide. Many copper-base alloys exhibit varying degrees of resistance to biofouling (2). Copper alloy CA-706 is reported to have excellent erosion-corrosion as well as antifouling properties proven by several engineering structures used in different environments (2-7). The composition of CA-706 is given in Table 1.

Based on extensive economic and technological assessments of how to build large composite ship hull structures, the two most promising avenues looked to be sheathing and cladding (8-9).

Sheathing may be defined as the use of Cu/Ni alloy sheet which is bonded in situ to steel plates already erected as ship hulls or ship modules. Cladding can be defined as a bimetallic material composed of a carbon steel substrate to which, on one side only, a layer of Cu/Ni alloy is already metallurgically bonded when received for construction.

TABLE I

Chemical Composition of Alloy CA-706

(Values given in weight percent)

Cu	Ni	Fe	Mn	Pb	P	S	C
88.6	9.0 - 11.0	1.0-1.8	1.0 max	.02 max	.02 max	.02 max	.05 max

While prior studies on cladding indicated technological feasibility it was found to have certain disadvantages relative to the sheathing approach. These drawbacks include higher purchase price, composite plate size limitation, and its use largely limited to new or special constructions. Sheathing, on the other hand, is much more versatile in that it lends itself to retrofit, new construction, and easier automation. Furthermore, the initial purchase price of sheathing is considerably lower.

II. PROCEDURE

Two state-of-the-art application methods considered for sheathing a steel hull were:

1. 100% peripheral (seam, butt or fillet) weld,
2. 100% peripheral weld plus slot weld.

In the initial laboratory phase small Cu/Ni test coupons of 3" x 6" x .10" (76.2 x 152.4 x 2.5 mm) size were used on ABS Grade B steel samples of 10" x 16" x .75" (254 x 406.4 x 19 mm) dimension. The size of the clad sample was 4" x 12" x 1" (101.6 x 304.8 x 25.4 mm). In the final laboratory phase only the sheathing method was tested using sample sizes of 3' x 5' x .10" (91.44 cm x 152.4 cm x 2.5 mm) for the Cu/Ni and 7' x 12' x .4375" (213.4 cm x 365.8 cm x 11.1 mm) for the steel plate.

On every steel sample three Cu/Ni coupons or panels were welded to duplicate the sheathing arrangement on the ship hull. A schematic drawing of the arrangement is shown in Figure 1. The graphical illustration of the clad sample and the sequence of its welding can be seen in Figure 2.

Of the fusion arc welding processes, the shielded metal-arc and the gas metal-arc welding were chosen. Both weld methods were evaluated in all welding positions. The respective weld data can be found in Table II.

### **III.A. WELDING OF CU/Ni SHEATHS TO STEEL PLATES**

#### **(a) Gas Metal-Arc Welding**

The increase in weld productivity is an important factor in safeguarding the future of any shipyard. With that in mind, the gas metal-arc welding (MIG) was first evaluated for welding Cu/Ni-Fe/C dissimilar materials. The list of parameters investigated with MIG is given below.

- \* Gap sizes of .125", .250", .375" and .500" (3.2-12.7 mm) between adjacent Cu/Ni panels,
- \* Low, normal and high weld heat input,
- \* Typical rust on steel, clean to "white metal" and shotblast-and-preproduction zinc rich primed steel surface,
- \* Flat, horizontal, vertical down and overhead weld positions,
- \* Peripheral weld,
- \* Peripheral weld plus slot weld
- \* Argon/Helium (75/25%) and pure Argon (100%) shielding gas.

Factors held constant were as follows:

- \* Monel 60 (ASW A5.14 Class ER NiCu-7) filler metal,
- \* Weld wire diameter .035",
- \* Shielding gas flow rate @ 12.5 ft<sup>3</sup>/hr,
- \* Direct current reverse polarity (DCRP).

TABLE II

Some of the Principal Welding Data Used in the Final Laboratory Phase

Welding Process	Welding Current (Amps)	Voltage (Volts)	Current Type and Polarity	Filler Metal		Shielding		Pre-Heat	Post-Heat
				Type	Size	Gas	Flow Rate (ft <sup>3</sup> /hr)		
SMAW	80, F*	-	DCRP	ENiCu-2	3/32"	-	-	None	None
	80, H*	-	DCRP	ENiCu-2	3/32"	-	-	None	None
	75-80, VU*	-	DCRP	ENiCu-2	3/32"	-	-	None	None
	75, OH*	-	DCRP	ENiCu-2	3/32"	-	-	None	None
MIG (1)	230, F*	24	DCRP	ERNiCu-7	.035"	100% Ar	12.5	None	None
	230, H*	24	DCRP	ERNiCu-7	.035"	100% Ar	12.5	None	None
	230, VD*	24	DCRP	ERNiCu-7	.035"	100% Ar	12.5	None	None
	180, OH*	22	DCRP	ERNiCu-7	.035"	100% Ar	12.5	None	None

\* F - Flat Position  
 H - Horizontal Position  
 VU - Vertical Up Position  
 VD - Vertical Down Position  
 OH - Overhead Position

(1) Welding currents indicated pertain to "Normal Heat Input" conditions (@ wire speed of 8 ipm for F, H, VD, and @ 6.4 ipm for OH)

Note: The maximum allowable interpass temperature for SMAW: in OH 200°F  
 VU 350°F  
 H & F not important (to make good welds)

Penetration of the weld into the steel substrate was found to be a function of the amount of rust present on the steel, the size (width) of the gap between adjacent Cu/Ni sheaths and the weld heat input, all else being constant. Figure 3 shows the gap size plotted against the width of weld penetration. The graph also indicates the percentile lack of penetration (LOP).

The magnitude of the crack-like discontinuity (CLD) present at the intersection of the copper/nickel-steel-Monel weld is very much influenced by:

1. Gap size
2. Steel surface condition with respect to rust
3. Fit up of Cu/Ni on Fe/C

Imposition of hydrodynamic conditions on hull weldments provide a preference for a weld profile flush with the Cu/Ni sheets.

In the liquid state, the surface tension of Monel 60 weld wire and the inferior wetting conditions of the weld joint made it impossible to obtain a smooth, flush weld profile. In the flat, the horizontal and the overhead positions the weld had a very pronounced reinforcement and in the vertical down position a concave configuration. Single pass welds in small gaps produced too much LOP and unsatisfactory weld shape in all weld positions regardless of weld heat input.

While some sporadic spatter and minute surface porosity occurred with MIG welding, their occasional presence is not viewed with concern. In terms of minimal LOP, the optimum gap size seems to be .5" (12.7mm). The ideal sequence of weld passes to fill such a gap is to perform two fillet welds - one on each side of the joint - and one fill-in pass. This weld practice hereinafter shall be referred to as "2f+f-i" and is highly advisable in all weld positions. The fillet welds are to ensure adequate "nailing" of the copper/nickel panels to the underlaying steel hull plate. The fill-in pass serves primarily as a "leakproof" and profile satisfying weld pass. Figure 4 shows the "2f+f-i" weld sequences, graphically.

The role of interpass temperature with Monel 60 MIG welding is extremely important: in overhead weld position the most critical. No acceptable weld could be made in OH position irrespective of heat setting, travel speed and substrate temperature. The preproduction zinc rich primer coating had no detrimental effects upon the weld quality.

(b) Shielded Metal-Arc Welding

Perhaps the most widely recognized merit of the shielded metal-arc (SMA) welding is that joints which are reachable with an electrode of the proper diameter can be welded in virtually any position. In welding hulls of large ships such an attribute has a special significance. The SMA process, on the other hand, has one notable shortcoming; i.e., low productivity.

The approach to SMA welding of Cu/Ni-Fe/C composites was similar to that used in MIG. The parameters investigated included:

- \* Gap sizes: .125", .250", .375", .500", .625"
- \* Interpass temperature
- \* All weld positions
- \* Peripheral weld
- \* Peripheral weld plus slot weld
- \* Rusted Steel
- \* Rust-free steel

Monel 190 (AWS A5.11 Class ENiCu-2) electrode size 3/32" (2.38 mm) and DCRP were used in the SMA experiments. The "2f+f-i" weld sequence was utilized as in the MIG evaluation tests.

Requirements for rust removal, mitigation of CLD are governed by the same considerations elucidated in conjunction with MIG welding. Again, the presence of preproduction zinc-rich primer posed no problem. Table III portrays SMAW requirements. Figure 5-6 show the action and the result of shielded metal-arc welding of Cu/Ni-Fe/C ship hull composite material.



TABLE 111

SMAW Requirements for Optimum Results in Specific Weld Positions

Weld Position	Welding				Electrode			Interpass Temperature (°F)	Gap Size Between Cu/Ni Panels (in)
	Current (amps)		Type	Polarity	Type	Size (in)			
	"2f"	"f-i"				"2f"	"f-i"		
F	80	120	DC	R	Monel 190	3/32	1/8	*	3/8
H	80	120	DC	R	Monel 190	3/32	1/8	*	3/8
VU	75-80	90-120	DC	R	Monel 190	3/32	1/8	350 max.	5/8
OH	75	75	DC	R	Monel 190	3/32	3/32	200 max.	3/8

\*Not important from the standpoint of making a sound weld.

NOTE: (a) Voltage was not measured. Used 0C setting.

(b) Weld current for slot welding should be 5 amps higher than that of corresponding weld positions for peripheral welds.

### 111. B. WELDING OF CU/NI CLAD STEEL PLATES

#### (a) Shielded Metal-Arc Welding:

The practice of welding Cu/Ni clad steel in essence consists of a two-step approach. First, the steel side root pass is welded by E6010, size 5/32" (3.97mm), DCRP. The joint preparation on the steel side involved single "V" with 60° included angle and 1/16"-1/4" (1.59-6.35mm) land. The purpose of the land is to prevent dilution. The root opening ranged from zero (0) to 1/8" (3.18 mm) in increments of 1/16" (1.59 mm).

In welding the clad side, two different joint preparation procedures were evaluated.

- (1) Groove or joint preparation by means of air carbon-arc with carbon rod diameters of 3/16" (4.76 mm) and 5/16" (7.94 mm) so as to determine the minimum groove size necessary to insure acceptable weld quality using Monel 190, size 3/32" (2.38 mm) electrode. Backgouging was extended into the root pass of the steel side welds to remove entrapped slag inclusions.
- (2) Backstripping of the Cu/Ni cladding up to 3/8" (9.53 mm). on both sides of the joint. Backgouging of the steel root pass and welding were along the lines outlined above. The 1/8" (3.18 mm) root opening is preferred to the tight root (or nose), especially with the backstripping method. The root opening of this magnitude requires less time to backgouge, causes less slag entrapment and provides an easier access to the making of the steel side root pass. The welding current for E6010, size 3/16" and E6027, size 5/32" was 130 amps, DCRP. The clad side welding current ranged from 85-90 amps, DCRP.

#### IV. STRUCTURAL INTEGRITY ASSESSMENTS

The mechanical and metallurgical characterization of copper/nickel-steel composite material is essential to the prediction of its behavior in service. Today, a limited applied engineering knowledge exists about the elastic and plastic behavior of this composite assessed under either laboratory or field conditions. This is particularly true for hull applications of large surface vessels.

##### (a) Metallurgical Investigations

The base steel had a ferrite-pearlite microstructure characteristic of a carbon-manganese steel (ABS Grade B). In going through the respective heat affected zones the microstructures and the grain sizes changed under the influence of the weld heat input due to a temperature gradient. At the weld metal-steel interface, there was some evidence of copper "fingers" running down the austenite grain boundaries. Microcracks and crack-like discontinuities were on occasion noted in this region. The copper/nickel HAZ showed a fine dendritic microstructure changing to selective melting along the grain boundaries of the base copper/nickel. The Monel 190 weld displayed a coarse dendritic microstructure. The base copper/nickel exhibited a recrystallized grain structure with evidence of twinning and alloy segregation.

As expected, hardness measurements traversing the base metals, the HAZ's and the weld illustrated a change in hardness values. The relative hardness values are indicative of the changes in the microstructure.

##### (b) Mechanical Testing

To gain some insight into the behavior of Cu/Ni-Fe/C composite weldments under static and dynamic loading conditions a few small samples were tested at ambient temperature. The static tests involved tensile testing of the base copper/nickel and lap shear testing of butt and slot welds. The dynamic tests consisted

of low-cycle fatigue of the tension-compression (alternating stress) and pulsating (tension-tension) mode.

The mechanical properties of the base copper/nickel agreed with published values for the annealed ("0" temper) condition. Due to geometric effects (stress concentrations) and residual stresses, the ultimate tensile strength of the copper/nickel at the weld is less than that of the non-welded Cu/Ni, but is above the yield strength of the base Cu/Ni. The lap shear stress of both the butt and the slot welds is greater than the ultimate tensile strength of the base Cu/Ni alloy. In other words, failure under overload conditions should normally occur in the Cu/Ni HAZ, as in fact it did. Fatigue failure also occurred in the Cu/Ni HAZ starting at the crack-like discontinuity (CLD). CLD is formed by the inherent geometry of the steel substrate, the copper/nickel panel and the Monel 190 weld joining the dissimilar metals together. A stress concentration is always inherent in such configurations. One fatigue test sample failed in the base steel at some gross weld discontinuity. This suggests the need to examine the significance of weld discontinuities leading to the establishment of weld acceptance standards.

## V. ECONOMICS

Like everything else, the ultimate viability of the Cu/Ni ship hull sheathing as a concept is measured by its economics. On one side of the economic balance is the initial investment (see Figure 7); while savings on the other (Figure 8). The elements of savings may conveniently be categorized as major, minor and miscellaneous. The major elements of savings for ship owner/operators come from lower fuel consumption, decreased dry docking, reduction in shaft horsepower requirements and propulsion plant size.

In the past, the cost of fuel, dry dock refurbishing methods and other attendant losses were relatively low. Hence, the cost differential between conventional, painted steel hull and clad or sheathed steel hull mitigated against the application of copper/nickel.

In the 1970's, notably in 1973 and 1979, the price of crude oil suddenly escalated so much so that today the single biggest expense in operating large ships is tied up in fuel. Reportedly, fifty percent of the total cash flow for ship owner/operators is associated with fuel consumption. This and the heightened inflation worldwide hurled the Cu/Ni concept into prominence as an attractive economic counter-measure.

In the minor savings category are increased profit, reduction in revenue losses, and scrap value of Cu/Ni at the end of the useful life of a ship. A list of miscellaneous savings considerations may consist of larger cargo capacity arising from a reduction in propulsion plant size, investment tax credit potential through governmental policies, increase in ship speed due to a smoother hull surface.

It is fair to state that a precise economic assessment and forecast can at best be approached if the exercise of economic modelling is tailored to a specific ship scenario. So, our economic analysis took the approach of selecting a container ship with its engineering specifics, sea-going environments and assumed annual operating days as shown in Figures 9 and 10.

The initial investment of Cu/Ni sheathing was based on modular construction using a combination of SMA peripheral and slot welding attachment methods and a 10% profit. This approach gave rise to an estimated cost differential between conventional coating and sheathing of \$3.4 million. Further conservative assumptions included 2 mils for the roughness of sheaths remaining constant and precluding biofouling for the life of the sheathed vessel. A conventional painted steel hull has an initial roughness of about 5 mils MAA (Mean Apparent Amplitude). With a typical hull maintenance of sand brushing and recoating on a biennial schedule, the hull surface continues to degrade with time at an assumed rate of 1 mil per year. In addition, fouling has to be reckoned with so far as conventional painted steel hulls are concerned. For that, 1 mil of roughness per

year was used in the economic calculations. Both the conventional and the composite ship were taken to operate at the same speed over the 20 year assumed operational life of the respective ships.

Several authors (10-14) studied the effect of hull roughness on changes in power requirements. A plot of increasing power requirement as a function of years-in-service after Professor Benford (10) is given in Figure 11. An empirical relationship between increasing shaft horsepower and hull roughness differential between a painted hull and sheathed hull proposed by Townsin (11) is also shown in Figure 11. The so-called "saw tooth effect" of the power vs years-in-service graph is the result of periodic hull cleaning of conventional painted steel hulls.

The 1980 cost of bunker "C" fuel was taken at \$21.00 per barrel representing U.S. oil price. It is worth pointing out that the international price of crude is substantially higher than that of domestic oil (\$32-35/bbl as of June 1980). Fuel, dry docking and scrap value of Cu/Ni were escalated at an annual rate of 10% over the life of the Cu/Ni sheathed vessel. The computer input data are illustrated in Figure 12.

For an effective discounted cash rate of return and zero-interest break-even point, 33.45% and 4.22 years after the start of ship construction (i.e., 1 year construction + 20 year ship life = 21 years) were obtained, respectively.

There are several additional benefits that may be derived from Cu/Ni sheathed ships. The present economic model assigns no credit to the real possibility for an appreciably longer useful life for the Cu/Ni sheathed ships than their conventional counterparts. Finally, favorable governmental policy through such measures as investment tax credit should pave the way for still another advantage to be realized with Cu/Ni by U.S. ship owner/operators. As for the Cu/Ni clad steel, the high material cost still negates its application for large ship hulls based on 1980 domestic oil price. However, it is economical for special constructions.

## VI. CONCLUSION

### (\*a) Sheathing

Of the many possible application techniques, two of the more common fusion-arc welding methods were examined.

Copper/Nickel can be welded to commercial ship hull steel satisfactorily in all weld positions by the shielded metal-arc welding process. The preferred weld pass sequence consists of two fillet welds and fill-in pass(es). This "2f+f-i" weld practice ensures the welding of the Cu/Ni panels to the steel substrate and helps provide a leak-proof weld as well as a flush weld profile. The surface appearance of the weld in terms of profile was best when Monel 190 electrode size 3/32" for "2f" and 1/8" for "f-i" was used in F, H, and VU positions. In the OH position, the 1/8" size electrode was found too large.

The gas metal-arc welding using Monel 60 size .035" solid wire electrode gave unsatisfactory results notably in out-of-position welds. In F and H positions, the weld had an excessive reinforcement. The weld profile showed too much concavity in VD position, while in OH position no acceptable weld could be made continuously due to fluidity problems of the filler metal. The interpass temperature in out-of-position welding with GMAW in particular was found to be extremely important. The maximum interpass temperature in OH and VU should not exceed 200° F and 350° F, respectively.

The presence of preproduction primer coating posed no problem in either SMA or GMA welding of Cu/Ni-Fe/C composite.

A brief mechanical characterization of Cu/Ni-Fe/C weldment showed under low cycle loading conditions that fatigue crack propagation would normally occur in the HAZ of Cu/Ni sheath, initiated at an inherent crack-like discontinuity being at the Copper/Nickel - Steel - Monel interface.

An economic analysis of Cu/Ni sheathing of hulls of large commercial ships produced very attractive results. Against an initial incremental investment of \$3.4 million and using 46% tax rate, the effective discounted cash rate of return and the zero-interest breakeven point were calculated to be 33.5% and 4.2 years, respectively.

(b) Cladding

There are two common ways of preparing the weld joint in clad steel: (1) groove the steel side with 1/16-1/8" land in the steel to prevent dilution, arc-air the groove on the clad side or (2) groove the steel side to the steel-cladding interface and backstrip the cladding. In either case, a 1/8" root opening minimizes slag entrapment and backgouging.

Irrespective of joint preparation methodologies selected, the actual welding sequence of Cu/Ni clad steel is as follows. Weld the steel side with the appropriate steel filler metal first (in our case: E6010 and E6027), backgouge the steel root pass prior to welding the Cu/Ni clad side with Monel 190 filler metal.

While the Cu/Ni clad steel for ship hulls is not as economical as the sheathing method, the Cu/Ni clad steel is cost-effective for special requirements.

VII. RECOMMENDATION

In view of the favorable technological and economic results, recommendations were made to test the copper/nickel sheathing and cladding methodology on a commercial ship in an actual ocean-going environment. Figure 13 shows the installations of copper/nickel on a fast (26 knots) container ship (DWT: 29,896 metric tons).



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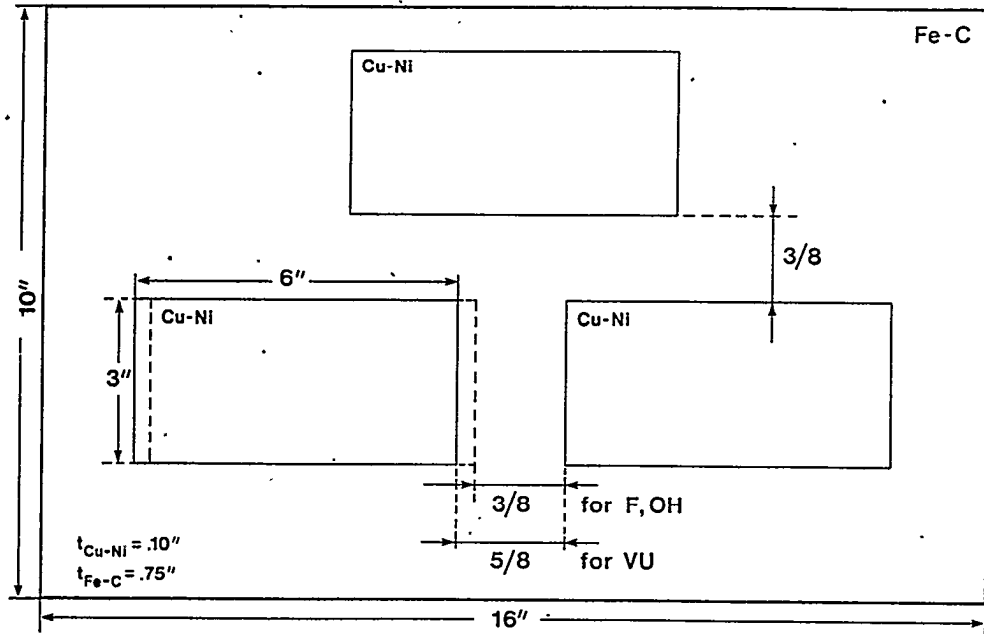
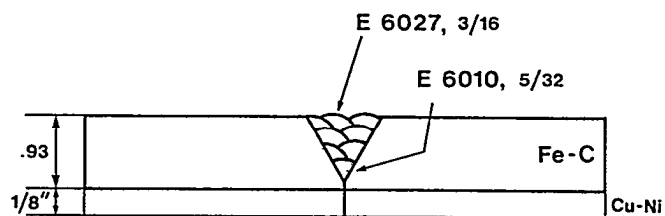


Fig. 1 - Scheme of Arrangement of Cu/Ni sheaths on steel.

## WELDING OF CLAD STEEL:

### STEP 1.



### STEP 2.

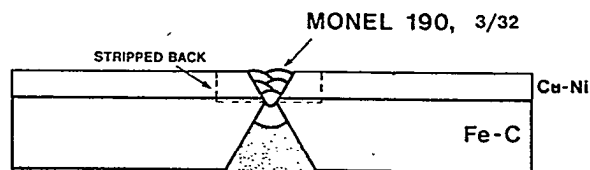


Fig. 2 - Graphical illustration of the welding of Cu/Ni clad steel.

# **ORIGINAL GAP SIZE BETWEEN Cu-Ni SHEATHS VERSUS WIDTH OF PENETRATION INTO STEEL SUBSTRATE OBTAINED**

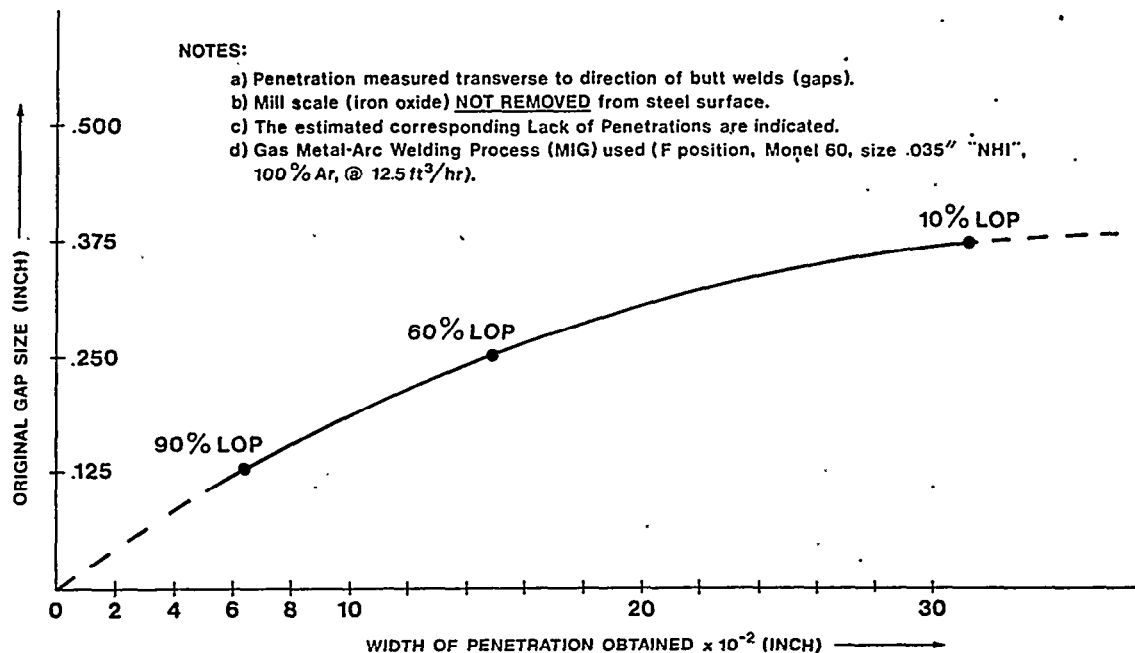


Fig. 3- Plot of gap size versus width of weld penetration into the steel substrate for constant "Normal Heat Input" and travel speed conditions.

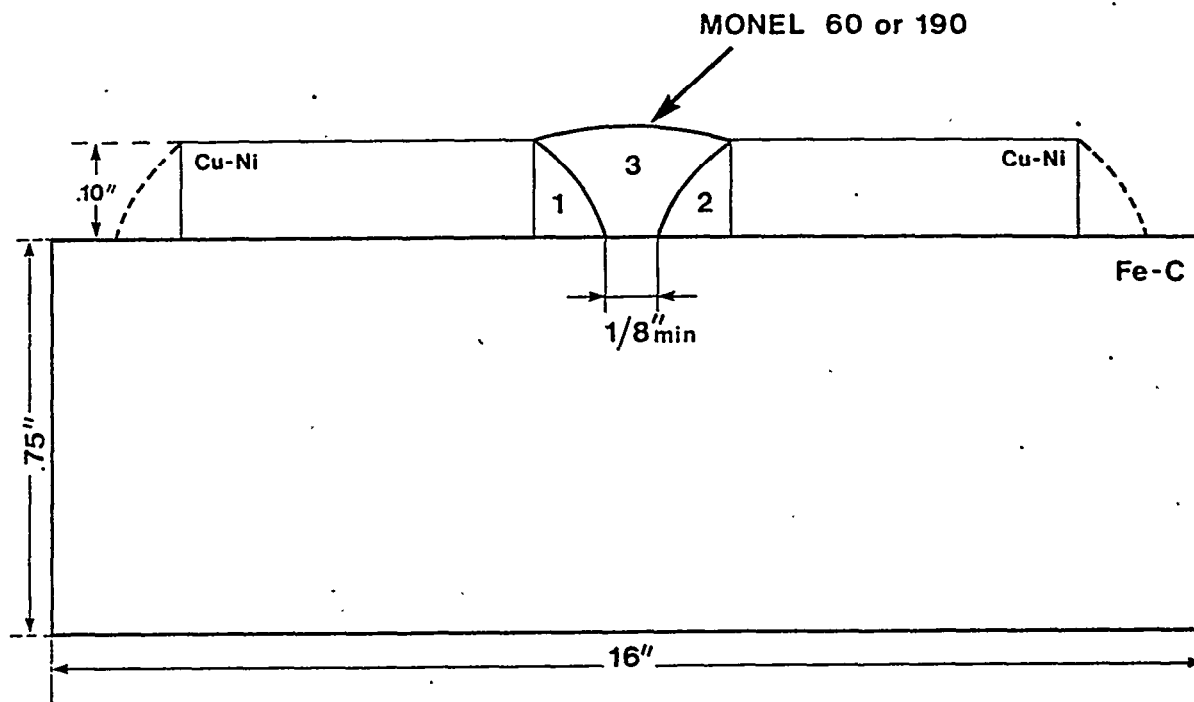


Fig. 4- "Fillet welds and fill-in pass" methodology for welding Cu/Ni sheaths to the underlying steel hull plate.



Fig. 5 Peripheral welding in the vertical-up position using SAW

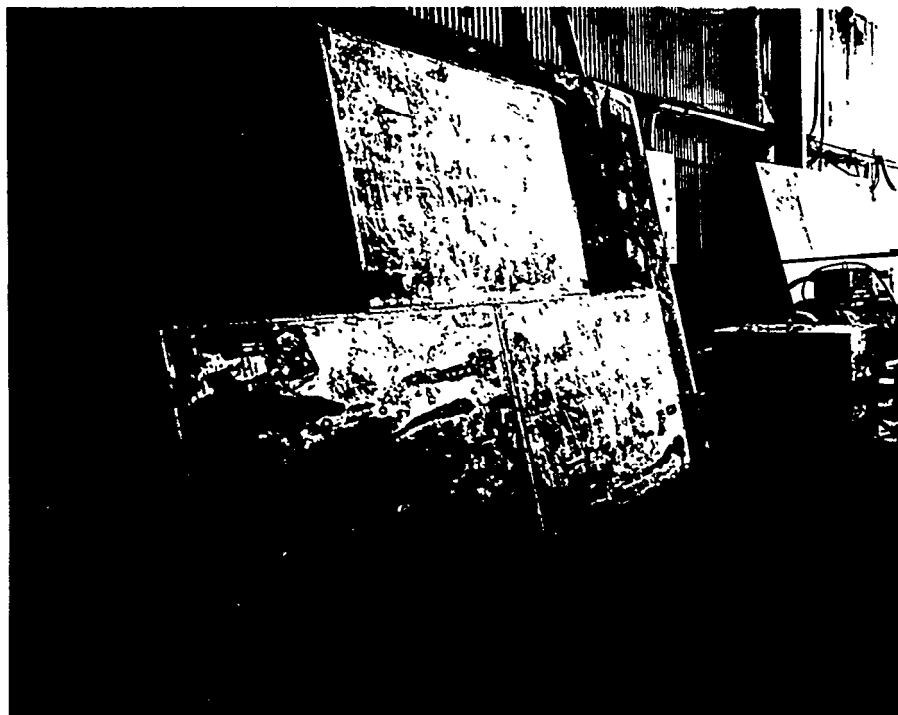
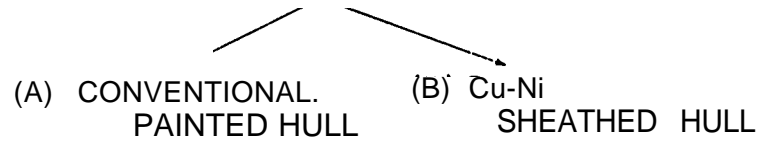


Fig. 6 A general overview of three Cu/ni sheaths welded to a primed steel plate in horizontal and vertical (butt weld between the two sheaths on the bottom and fillet welds on the ends of each sheath) position.

# INITIAL COST ELEMENTS



A.1 shotblasting + material	B.1 sheathing material
A.2 painting + material	B.2 welding
A.3 add'l. staging for A 1 & A 2	B.3 grinding all welds
A.4 labor rates for A.1-A.3	B.4 fitting & tacking
A.5 drydock & services	B.5 setting-up work area
A.6 incidentals	B.6 construction services
	B.7 engineering
	B.8 100% NDT
	B.9 punching slots and/or adhesive(s)
	B.10 profit (10%)
-TOTAL = S.4 Million	\$3.6 - 3.9 Million

$$\Delta \overline{AB} = \$3.4 \text{ M (average)}$$

Fig. 7 Initial cost elements.

# MAJOR ELEMENTS of SAVINGS

CONSIDERED for Cu-Ni

1. FUEL

2. REDUCED DRY-DOCKING (Biennial & Quadrennial)

3. ADDITIONAL REVENUE and PROFIT

4. PROPULSION PLANT REDUCTION

5. SCRAP VALUE of Cu-Ni

	PURCHASE	SCRAP
Cu-Ni PRICE:	\$2.6946 per lb.	\$1.17 per lb. (minus labor) <sub>50yo</sub>

## ESTIMATED SAVINGS DUE TO 2. & 3. above

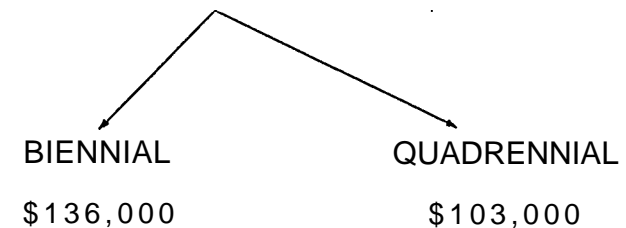


Fig. 8 Major elements of savings.

# ECONOMIC ASSESSMENTS

## NEW CONSTRUCTION

e.g.: Hull # 678 (container ship)

677' LBP 95' BEAM 54' DEPTH

23knots @ 29.5' Draft 26,352 DWT

.4849 lb/SHP-HR @ Max. Power

30,000 SHP (108 RPM)

1,065 barrels/day

Bunker "C" \$21.00/barrel  
(U.S.A. price, March 1980)

(international price is higher)

79,000 ft<sup>2</sup> WETTED SURFACE

INFLATION ESCALATOR (over 21 years): 10%

ANNUAL OPERATING DAYS: 300

ANNUAL FUEL CONSUMPTION: \$6.0 Million @ 87 % rated SHP

## INCREMENTAL POWER REQUIREMENTS

(Due to roughening of painted HULLS)

YEAR	$k_p$ [mils]	$\Delta P$ [%]
1	6	9.5
2	8	12.6
3	8	12.6
4	10	15.2
5	10	15.2
6	12	17.5
7	12	17.5
8	14	19.5
9	14	19.5
10	16	21.4
11	16	21.4
12	18	23.1
13	18	23.1
14	20	24.7
15	20	24.7
16	22	26.2
17	22	26.2
18	24	27.6
19	24	27.6
20	26	28.9

Fig. 9 Engineering specifics of a container ship used in the economic assessments.

Fig. 10 Additional factors taken into account of the Cu/Ni hull sheathing economics.

• Average (MAA) = initial + deterioration + fouling

•• Ref.: Townsin's paper;

$$100 \frac{\Delta P}{P} = 580 \left[ (k_p)^{1/3} - (k_{CN})^{1/3} \right]$$

where,

$100 \frac{\Delta P}{P}$  = required increase in SHP due  
to increasing roughness  
of painted hull [%]

$k_p$  = surface roughness of painted hull  
[ MAA meters = MAA mils  $\times 25 \times 10^{-6}$  ]

$k_{CN}$  = surface roughness of Cu-Ni taken  
CONSTANT = 2 mils .

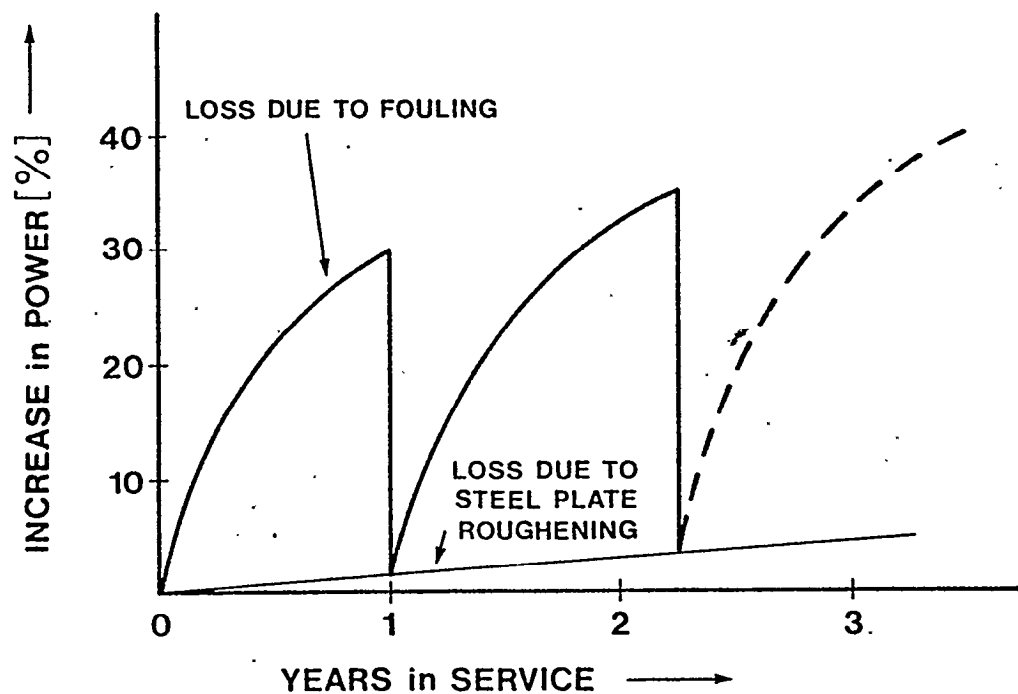


Fig. 11 Consequences of hull roughness due to fouling and base steel roughening with time on the shaft horsepower requirement.

CONSTRUCTION  
YEAR 1980

# COMPUTER INPUT DATA

No. of YEARS	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL SAVINGS (\$ Million)
FUEL	—	.658	.959	1.055	1.400	1.540	1.951	2.146	2.630	2.893	3.493	3.842	4.562	5.018	5.903	6.493	7.576	8.333	9.657	10.622	12.235	92.966
DD and REVENUE	—	—	.173	—	.158	—	.253	—	.232	—	.370	—	.339	—	.542	—	.496	—	.793	—	.727	4.083
12 % PP REDUCTION	400	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.400
Cu-Ni SCRAP	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.475	1.475
TOTAL SAVINGS	400	.658	1.132	1.055	1.558	1.540	2.204	2.146	2.862	2.893	3.863	3.842	4.901	5.018	6.445	6.493	8.072	8.333	10.45	10.622	12.962 + 1.475	98.924

w/ INITIAL INVESTMENT: \$3.4 Million & 46% Tax Rate

COMPUTER RESULTS:

ZERO-INTEREST BREAKEVEN POINT: 5.22 years or 4.22 yrs. FROM START-UP

**EFFECTIVE DCRR: 33.45%**

Fig. 12 Computer input data showing the results of economic analysis conducted.



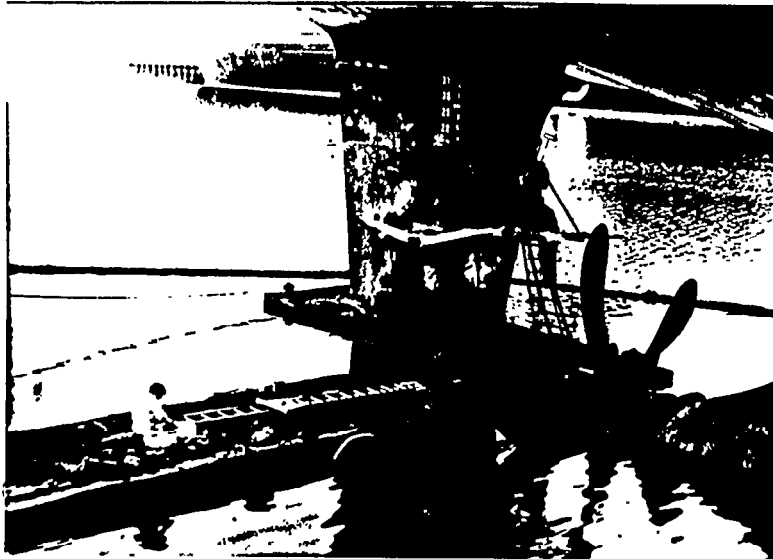
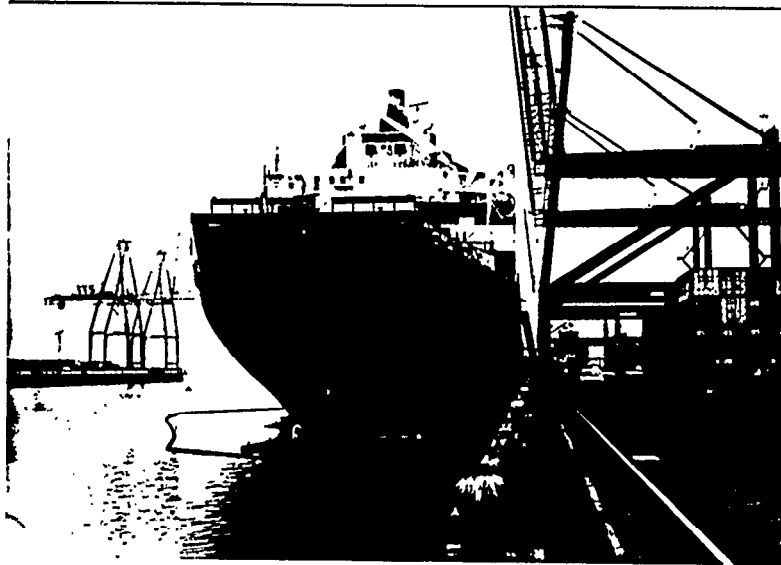


Figure 13. Installing copper/nickel on a fast (26 knots) container ship.

A CNC SHEETMETAL FABRICATION SYSTEM FOR PRODUCTION  
OF SHIPS VENTILATION COMPONENTS AND FLATWORK

Thomas R. Galie  
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David R. Blais  
Bath Iron Works Corporation  
Bath, Maine

ABSTRACT

The U. S. Navy has a need to produce more ships at lower cost. As documented by a recent study, present shipyard methods for fabricating ventilation and flatwork are key cost drivers in ship production. They consist of a multitude of repetitious operations, resulting in excessive manhours and material costs.

By utilizing computer graphics technology and Computer Numeric Control (CNC) machine tools, it is possible to reduce the manhours required for fabrication of ventilation and flatwork by as much as 40 percent. Benefits resulting from increased efficiency in materials use, in-process storage and production planning may also be realized by users. In addition, the U. S. Navy can benefit through a reduction in ship production costs, increased production capacity and spread of a new technology adaptable to many shipyards.

This paper discusses a joint effort by the Naval Ship Systems Engineering Station (NAVSES) and the Bath Iron Works Corporation (BIW) to develop and implement a Computer-Aided Manufacturing (CAM) system for cutting the cost of fabricating ventilation and flatwork in BIW sheetmetal operation. It is a cost-shared project, funded by the Navy under its Manufacturing Technology (MAN TECH) program.

Key topics presented will be: Sheetmetal Fabrication Process at BIW; CNC Sheetmetal Fabrication System Configuration; System Advantages, and Implementation Factors for follow-on users.

## 1.0 INTRODUCTION

In 1976-77, the U. S. Navy Manufacturing Technology (MAN TECH) Program Office conducted a study to identify key operations in Naval ship construction where new approaches to production could be developed and which could reduce costs and make more efficient use of U. S. shipyards capacity. This study identified the sheetmetal fabrication operation as a high cost driver within BIW. Further investigations conducted by NAVSSES confirmed this as a cost driver throughout U. S. shipbuilding. Consequently, based on a proposal from BIW, NAVSSES initiated the CNC Sheetmetal Fabrication System Project to develop a promising new approach to sheetmetal fabrication.

The vehicle used to fund this project is the Department of the Navy's Manufacturing Technology (MAN TECH) program. MAN TECH's basic objective is to improve the productivity and responsiveness of the defense industrial base. This is accomplished through projects which demonstrate specific applications of new and improved manufacturing technologies. Concepts, whose feasibility has already been shown in R&D, are often transferred and developed by industry in a proof-of-application effort. The application and benefits are then documented for use by the Navy and industry at large.

The CNC Sheetmetal Fabrication System is one such project. It was funded in 1979 and is well underway, with all of the hardware and much of the software in place at BIW. The current schedule will see system proveout completed by December 1981 with full documentation to follow.

The system integrates a Numerical Control Support System (NCSS) with a Direct Numerical Controlled (DNC) Sheetmetal Fabrication Center (SFC), which, together, automate that portion of the sheetmetal fabrication process which begins with the lofting operations and ends with the finished two dimensional component parts.

This paper starts with a description of current sheetmetal operations at BIW and describes the new system being developed which will automate these current operations. A discussion of the anticipated benefits for the Navy, BIW and follow-on users will also be presented.

## 2.0 SHEETMETAL FABRICATION PROCESS AT BIW

Shipboard sheetmetal products fabricated at BIW consist primarily of ventilation ductwork and of flatwork. Ventilation ductwork consists of a variety of components, the majority of which fall into a few generic shapes (ie: elbows, straights, transitions, reducers, twists and tees). Flatwork refers to all other products fabricated from steel material with maximum thickness of 1/4 inch (ie: gage boards, power panels, bulkhead curtain plates, electrical enclosure curtain plates and crew's lockers and berths).

Figure 1 diagrammatically depicts the current fabrication process used at BIW for both ventilation and flatwork. Note that the process initiates with a pre-existant ship's plan or engineering drawing from which a specific ventilation or flatwork shape will be defined as a "part". Templates for each part - for example, a centered rectangular to round transition or an under-deck curtain plate -- are then manufactured during the manual lofting

stage. In the case of a ventilation shape, this lofting operation also involves breaking the three dimensional ventilation part into an equivalent, properly scaled, two dimensional flat pattern. Then each flat pattern is further broken down into several individual pieces, which we, in the project, refer to as "piece-marks". Finally, a template for each piece-mark must be manufactured. Therefore, a multitude of templates, one for each piece mark, must be manufactured during lofting for a single ventilation part. After the lofting operation, each template is laid out by hand and scribed into sheet-metal stock. The stock is then rough sheared and the piece-mark or flatwork part is cut out and hand trimmed to final dimensions. If an access hole is required, this will be done next on a manual punch machine. The pieces are then identified and either stored as is, or assembled for immediate installation as finished parts.

As described, this process requires highly specialized labor skills to perform excessively repetitious, time consuming manual operation. The process is therefore easily recognized as labor intensive. Bulk storage of the valuable, reuseable templates is required, and this results in dedication of floor space which could be better used for manufacturing. This process also fosters an undesirable situation in which the sheetmetal shop must fabricate three to four complete ship sets of ventilation material ahead of the individual hull erection schedule.

### 3.0 CNC SHEETMETAL FABRICATION SYSTEM

The development of the CNC Sheetmetal Fabrication System is conceived as a viable, timely solution for the high cost of manufacturing ventilation and flatwork at BIW. It has also been acknowledged as a potential solution to similar costs drivers at other U. S. shipyards by the Society of Naval and Architectural Marine Engineers (SNAME) .

This system incorporates two modern technologies: Interactive Graphics and Direct Numerical Control of production machinery. The system itself is made up of two computer based modules: the Numeric Control Support System (NCSS) and the Sheetmetal Fabrication Center (SFC). Figure 2 is a diagrammatic comparison of the forthcoming new ventilation and flatwork production process versus the current process previously described. As shown, the NCSS module will replace the current manual lofting and manual layout operations; and, the SFC will replace the rough shearing, finish trimming and hole punching operations.

As presently conceived, these modules will be located in separate areas and will be linked by a "soft" medium, ie the "Job Diskette". This job diskette will contain all the parts definition and management data generated by the NCSS. This is the data which must be communicated to the SFC for fabrication of ventilation piece-marks and flatwork parts. Figure 3 is a schematic drawing showing the hardware layout for each of the two modules. Note the dashed line connecting the two modules. This represents the "soft" link.

#### 3.1 THE NUMERICAL CONTROL SUPPORT SYSTEM (NCSS)

The NCSS will be located in BIW's computer operations room and consists of a computer, highspeed printer/plotter, a graphics display terminal, a high speed magnetic tape drive, a dual floppy diskette drive and a cartridge module disk unit.

The function of the NCSS is to (1) interactively (person/computer) develop ventilation and flatwork parts production data and (2) automatically generate material management information, parts management information, production management reports and Numerical Control (NC) machinery control data. The system software will handle ventilation parts and flatwork parts separately and each in a very unique manner. BIW has developed a geometric set of twenty-nine standard ventilation shapes. This set is being programmed as a hardware independent software package and developed solely for the definition and production of standard ventilation shapes. We have estimated that in excess of 90% of all geometric requirements for ventilation parts will be covered by this set of standard ventilation shapes. All one-of-a-kind ventilation parts and all flatwork parts will be produced using a commercially available interactive graphics software package.

### 3.2 THE SHEETMETAL FABRICATION CENTER (SFC)

The SFC will be located in the sheetmetal shop and consists of a computer, a dual floppy diskette drive, an auxiliary data entry console and a commercial turret punch press with plasma cutting capability. Control data generated by the NCSS will be input into the SFC via the job diskette for the actual cutting or fabrication of both ventilation piece-marks and flatwork parts.

### 3.3 CNC SHEETMETAL FABRICATION SYSTEM OPERATION (CNS-SMFS)

The previous sections discussed the NCSS and SFC as separate modules which, when integrated, comprise the entire CNC Sheetmetal Fabrication System (CNC-SMFS). It was noted that this integrated system handles standard ventilation shapes and flatwork parts differently. This is shown in Figure 4. Note that the interactive graphics software package for flatwork (and one-of-a-kind ventilation parts)- is shown here as a CAD/CAM System. This part of the CNC-SMFS is conceived as user-specified, and therefore, will not be described further. The software for standard ventilation shapes is being developed under the project. The following discussion of the system operation will, therefore, center on the production of a standard ventilation shapes (the example will be a centered rectangular to round transition).

The CNC-SMFS is a menu driven system as depicted in Figure 4. The system requires two operators: the first operator will work out of the computer operations room and the second will work out of the sheetmetal shop. The first operator will refer to the engineering drawing and identify specific generic shapes that will be required for a single production run. He will then call to a particular entry in the "shapes menu" displayed on the graphics display terminal. The CNS-SMFS will respond by displaying a three dimensional line drawing of the selected shape. Assuming the operator has selected shape number 12, a rectangular to round transition will be displayed as shown in Figure 5. The CNC-SMFS will then prompt the operator to input identification information, material data, dimensional data and air flow direction. After the operator has verified all the data, the CNC-SMFS will display the properly dimensioned and scaled piece-marks. This display is, therefore, the 2-dimensional flatpattern equivalent of the specific 3-dimensional ventilation part defined. For shape number twelve, there will be two separate piece-marks, A and B, in the flatpattern, as shown in Figure 6. The operator now has the option of including a variety of access holes, if required. Figure 6 shows the inclusion of a round access hole in piece-mark B. At this point, the

operator has uniquely defined a specific ventilation part and may either return to the shapes menu to define a new part or initiate the nesting routine. If the operator has completed definition of all the parts for a production run, he will then begin nesting the individual piece-marks. Nesting is performed interactively as shown in Figure 7. The CNC-SMFS will call up each piece-mark in succession and the operator will either nest the part on a sized sheet on the screen or move onto the next piece-mark. When all nests for a production run are completed and verified, the CNC-SMFS will automatically process all the data and create a job diskette. This job diskette will include the post-processed NC data for driving the turret punch press, as well as the following reports:

- |                     |                |
|---------------------|----------------|
| -Components list    | -Nest drawings |
| -Material list      | -Labels        |
| -Shear list         | -Tooling list  |
| -Operator's listing | -NC listing    |

The job diskette, along with the operator's listing, nest drawings and labels are transferred to the second operator in the sheetmetal shop. This operator will then load the diskette into the CNC-SMFS's DNC link, place the proper material on the turret punch press and input a start command. After the CNC-SMFS has cut a duplicate of the nested drawing in the sheetmetal stock, the operator will affix labels to each piece-mark or flatwork part. The CNC-SMFS will control all cutting operations and leave small tabs between the cuts. These tabs enable the operator to off-load an entire finished nest intact. This completes the operation of the CNC Sheetmetal Fabrication System.

#### 4.0- SYSTEM ADVANTAGES

The primary advantage of this system is a reduction in current labor costs in the production of shipboard ventilation and flatwork. BIW estimates an overall labor manhour reduction of approximately 40%.

This is the net of the following percentage savings for specific operations and the moderate additional requirements for the newly added operations:

<u>Operations</u>	<u>Estimated Savings (% of Current Hours)</u>
Shearing	75
Layout	75
Punching	
Material Handling	20
Lofting	100
Special Fittings	25
Clerical	10

Additional benefits can be grouped as:

- materials use
- in-process storage
- production planning
- work throughput

Three materials-use benefits are anticipated. Computer nesting is expected to result in less generated scrap through closer nesting than typical with manual layout. The CNC-SMFS also allows common border locations for nested piece-marks and flatwork parts. The other materials use benefit concerns the increase in sheetmetal fabrication shop responsiveness. The system will be able to produce work on a more responsive basis by reducing the current long lead times in ship construction schedules.

In-process storage needs will be eliminated entirely for templates. A reduction in in-process storage of finished parts will also result from the decrease in ventilation production lead times.

Production planning will become more flexible and work throughout will increase since the impact of engineering changes will only result in paper changes and will not be realized in material waste.

For the Navy, benefits are accrued in two major ways. Both center around the opportunity for use of this new system concept, not only by BIW, but by other shipyards. First, the ship production cost is reduced through a reduction in production cost for ventilation parts and flatwork. This has the potential to result in a lower ship procurement cost for the Navy. Secondly, the potential for increased sheetmetal production capacity may add to the capacity of the industrial base.

## 5.0 CONSIDERATIONS FOR FOLLOW-ON USERS

The above benefits will make permanent system use at BIW attractive. While the situations at other yards will vary, it is possible that the system can prove similarly attractive for follow-on users.

Several key points related to follow-on use are worth raising. First, the CNC-SMFS software is portable for use with other hardware. The programming of standard ventilation shapes, in particular, is seen as an important advance.

Full documentation on the system will be available through the Navy when the project is completed. This will include source documentation on the standard ventilation shapes programs and notes on portability for follow-on users.

Finally, both the Navy and BIW will be pleased to discuss and demonstrate the experience gained in this project. An integral part of MAN TECH projects is the dissemination of information to industry to help increase the application of valuable projects. The experience to date in this project indicates that its value is high and that, from the Navy's standpoint, additional application of this technology and system concept is desirable.

## REFERENCES

- (1) "High Cost Areas of Ship Construction", prepared by Automation Industries VITRO LABORATORIES, DIV. under Navy Contract No. N00024-74-C-7108 Task No. 745, 14 Aug 1978.
- (2) Letter from SNAME, Mr. E. L. Peterson, to the Department of the Navy dated March 4, 1980.

FIGURE 1

CURRENT FABRICATION PROCESS

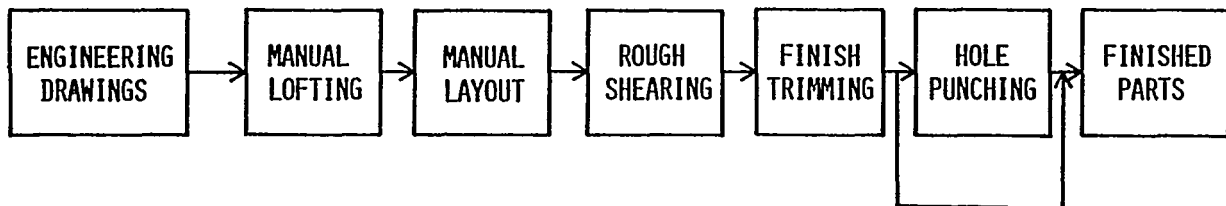
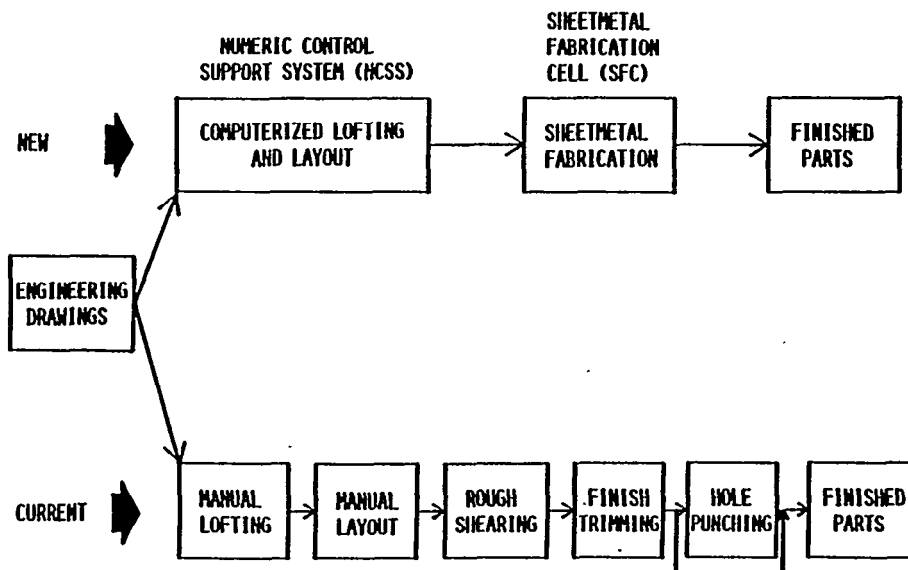


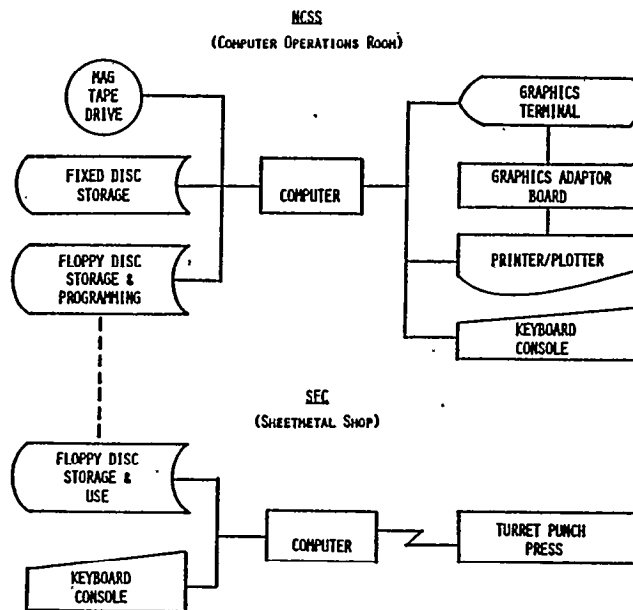
FIGURE 2

SHEETMETAL FABRICATION: NEW vs. CURRENT





**HARDWARE LAYOUT**  
**CNC SHEETMETAL FABRICATION SYSTEM**  
**FIGURE 3**



**FIGURE 4**  
**NEW SYSTEM**

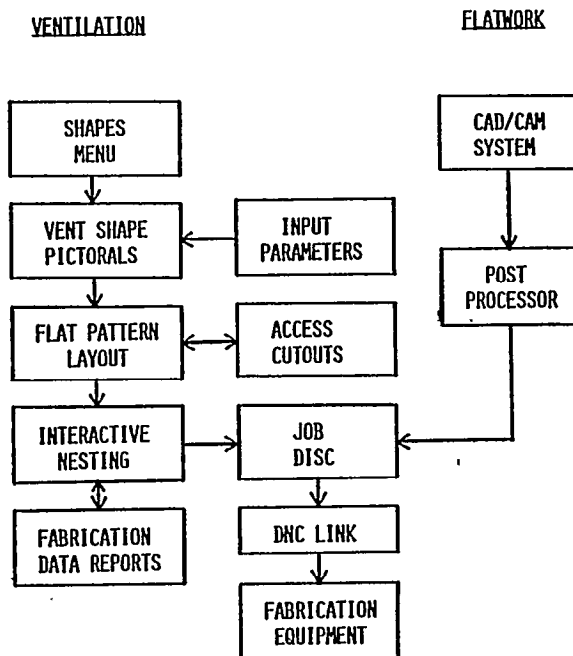


FIGURE 5  
INTERACTIVE STANDARD SHAPES DISPLAY

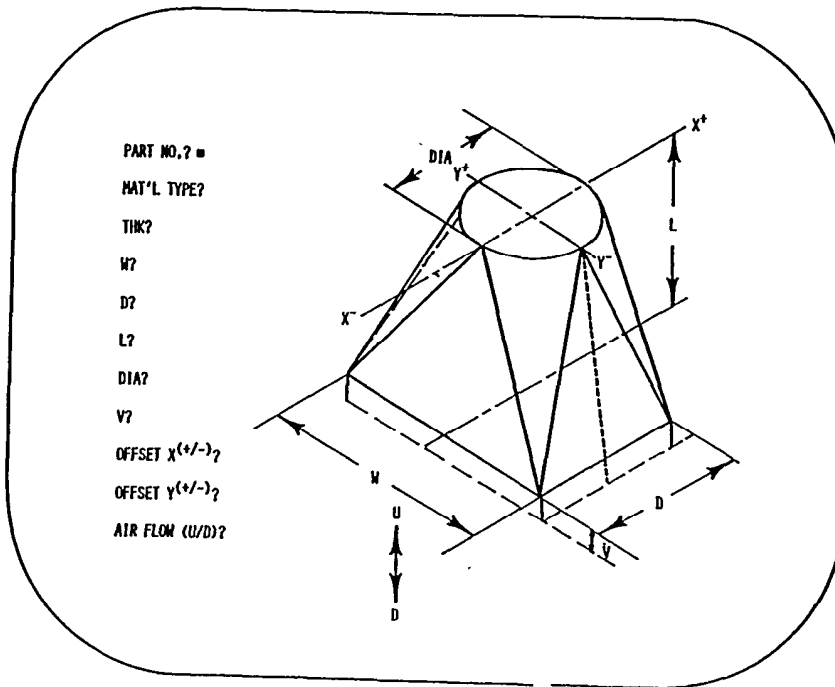


FIGURE 6  
FLAT PATTERN LAYOUT

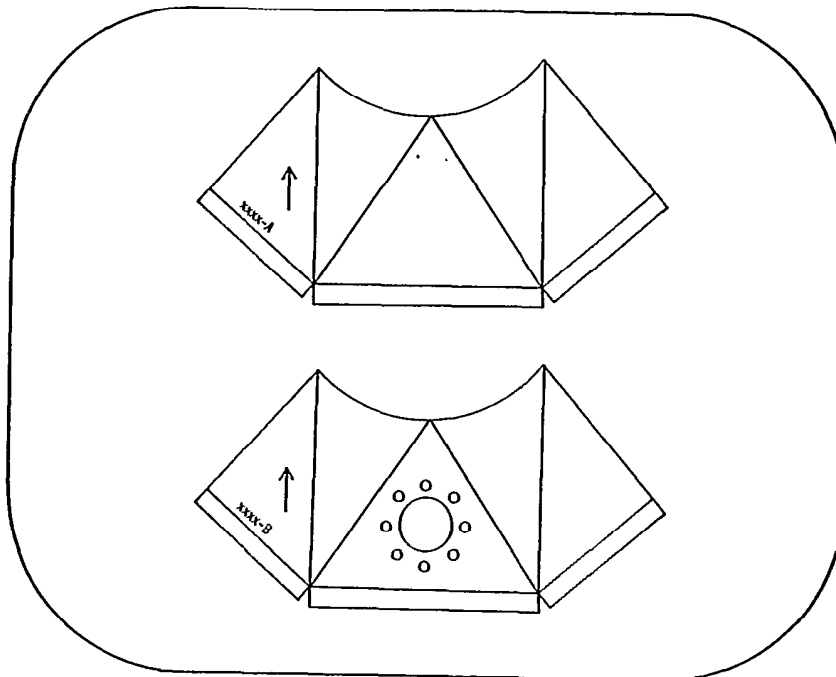
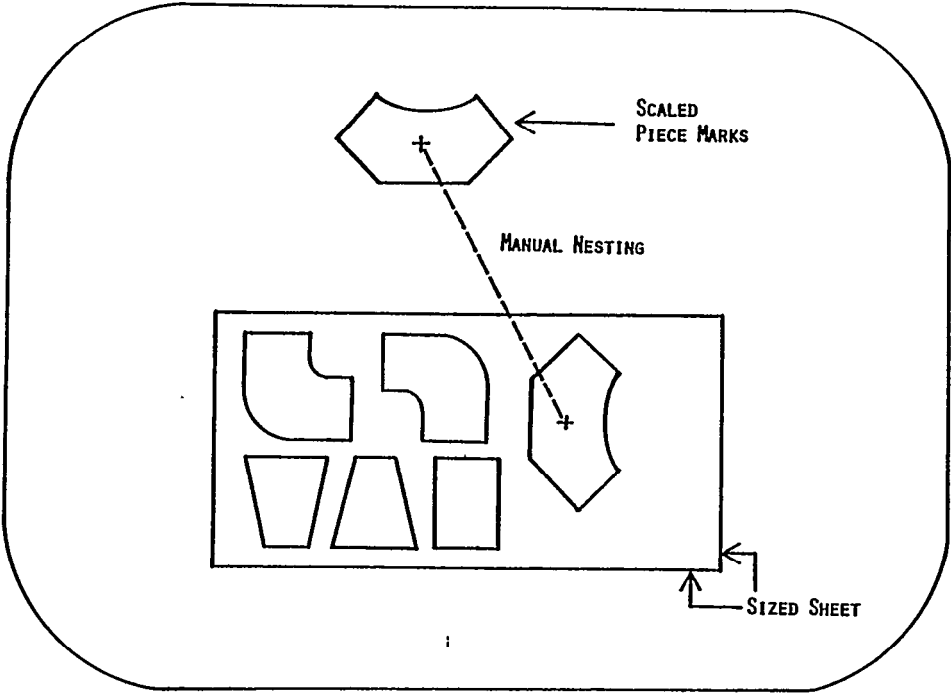


FIGURE 7  
COMPUTER-AIDED NESTING



## SHIP STRUCTURAL COST PROGRAM

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Structural Engineer  
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### ABSTRACT

A ship-cost computer tool has been developed to estimate U.S. Naval Surface Ship construction for both shop and field Engineered Uniform Method and Standards and current Naval shipbuilding practices.

This procedure has been incorporated into the Ship Structural Cost Program (SSCP) to provide a means of rapidly estimating structural cost for ship structures. In this form SSCP provides a three-phase cost analysis where the shop erection and field installation procedures are included in Phases 2 and 3 and the panel/grillage shop assembly procedures are included in Phase 1.

The overall aim of our cost program is to develop a cost/weight tradeoff tool that has the capability of performing weight/cost optimization tradeoff studies. This information will become useful for Navy research and design communities in assessing high cost areas in the new ship construction, identification of optimum plate-beam combinations with respect to cost and/or weight, and the identification of materials and design details which tend to reduce cost.



DAVID W. TAYLOR NAVAL SHIP  
RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20884



## SHIP STRUCTURAL COST PROGRAM

AUTOMATED COST ESTIMATING TOOL

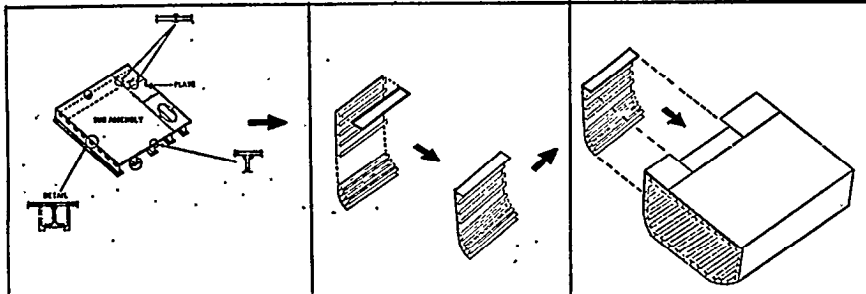
BASED ON NAVSEA

ENGINEERED UNIFORM METHODS & STANDARDS

FOR NAVAL SURFACE SHIP CONSTRUCTION

## SHIP STRUCTURAL COST PROGRAM SSCP

PHASE 1 - SUBASSEMBLY      PHASE-2 SHOP ERECTION      PHASE-3 FIELD INSTALLATION



SIGNIFICANT OPTIONS:  
GEOMETRY  
MONOHULL OR HIGH  
PERFORMANCE SHIP  
HULL AND/OR DECKHOUSE  
FLAT BAR STIFFENERS  
MATERIALS  
MS, HTS, HY80, ALUM  
DETAILS

CAPABILITIES:  
MATERIAL COST STUDIES  
CONFIGURATION STUDIES  
COST/WEIGHT OPTIMIZATION  
FUTURE IMPROVEMENTS:  
NEW DETAILS  
ALUM FIRE PROTECTION COSTS  
BALLISTIC PLATING COSTS  
WELD BONDS COSTS

# SHIP STRUCTURAL COST PROGRAM

## SSCP

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### OBJECTIVES

LONG TERM •DEVELOP COST/WEIGHT TRADE-OFF CAPABILITY FOR EFFICIENT  
USE OF MATERIAL & STRUCTURES

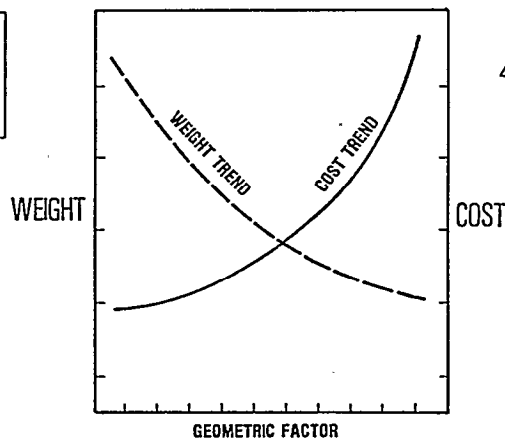
SHORT TERM •DEVELOP A COST ESTIMATION PROGRAM FOR SURFACE  
SHIP STRUCTURES

- INCORPORATE THE CAPABILITY OF NAVY DESIGN PROGRAMS  
WITH THE COST PROGRAM TO PERFORM COST/WEIGHT  
OPTIMIZATION STUDIES
- IMPROVE RELATIVE COST/WEIGHT TRADE-OFF CAPABILITY FOR  
R & D COMMUNITIES
- PROVIDE NAVAL SHIPYARDS WITH COMPUTERIZED METHOD FOR  
COST ESTIMATING REPAIR & CONVERSION
- EVALUATE HIGH COST AREAS OF SHIP CONSTRUCTION

### COST/WEIGHT TRADE-OFF

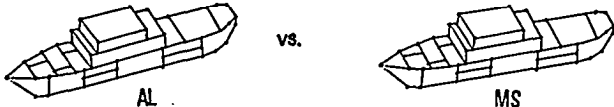




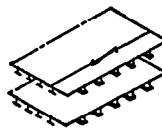
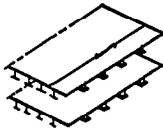
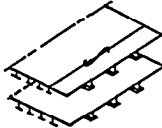
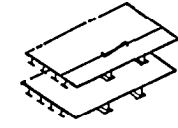
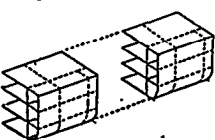
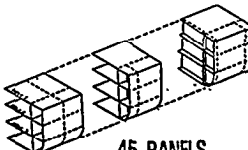
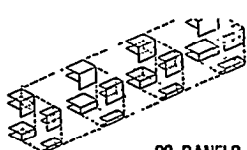
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**COST FACTORS**  
GEOMETRY  
LOADING  
MATERIAL COST  
PRODUCTION COST

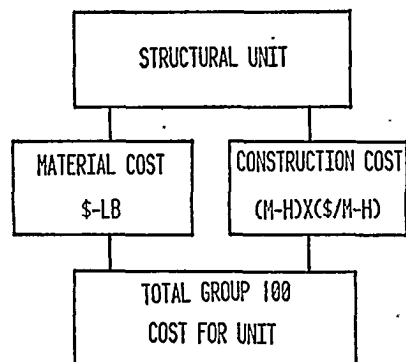


## SSCP APPLICATIONS

[RELATIVE COST COMPARISONS]

MATERIAL COST STUDY				
CONFIGURATION STUDY SCANTLINGS	 MS/HTS	 HY80	 HTS	 MS
COST / WEIGHT OPTIMIZATION STUDY	 6' F.S.	 8' F.S.	 10' F.S.	 12' F.S.
CONFIGURATION STUDY MODULAR	 36 PANELS	 45 PANELS	 63 PANELS	

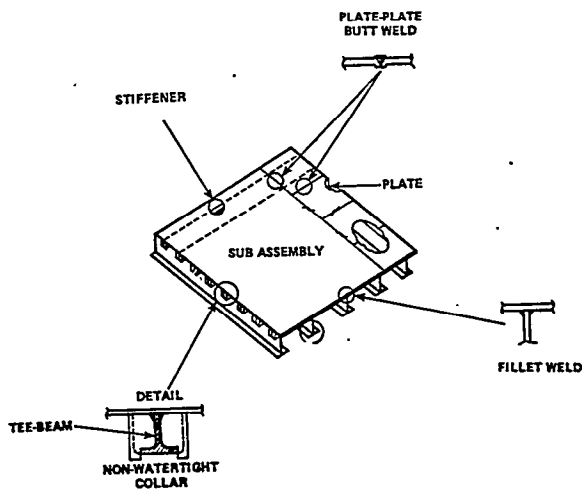
## BASIC CONCEPT



## PHASE 1-SHOP FABRICATION & WELDING

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COST
LOFTING
LAYOUT
CUT & BURN
ROLLING
ASSEMBLY
WELDING



### ENGINEERED UNIFORM METHODS & STANDARDS TITLE I STRUCTURAL-LOFT LAYOUT & MACHINE

---

#### ◦ LOFT

DEVELOP & BUILD TEMPLATES & DRAWINGS 1/10 SCALE (PLATES & SHAPES)

#### ◦ LAYOUT

TRANSFERRING TEMPLATES & DRAWINGS (PLATES & SHAPES)

### TITLE I BURN FLAME CUT PRODUCTION

---

#### ◦ PLATES

TELEREX 90° CUT

RADIOGRAPH BEVEL CUTTING

SAW CUT ALUM

SHEARING AL & ST

#### ◦ STIFFENERS & DETAILS

MANUAL HAND GUIDED

90° CUT & BEVEL CUTTING

SHEARING ALUM



**ENGINEERED  
UNIFORM METHODS & STANDARDS  
TITLE, ROLLING OPERATIONS**

---

PLATING MAN HOURS AREA FUNCTION OF PLATE THICKNESS & WIDTH OF ROLL

STIFFENERS- MAN HOURS AREA FUNCTION OF THE TYPE OF MACHINE OPERATION

**TITLE : STRUCTURAL SHOP ASSEMBLY**

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- o PLATE ASSEMBLY
- o STIFFENER ASSEMBLY
- o DETAIL ASSEMBLY
- o VAC-U-BLAST
- o PNEUMATIC SERVICES
- o BURNING & WELDING SERVICES
- o CRANE SERVICES

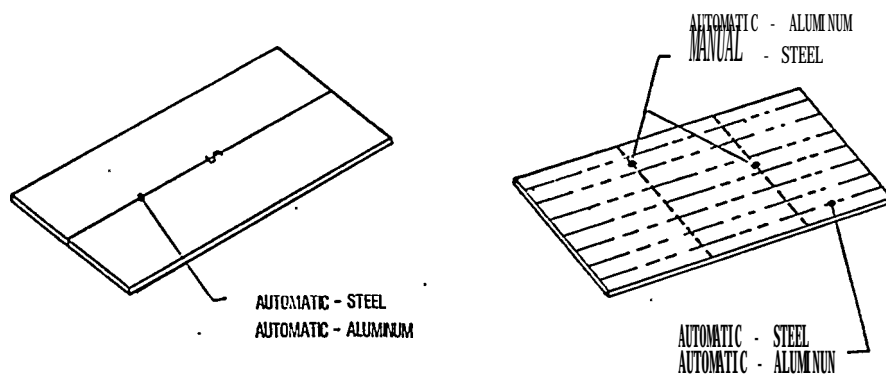
**TITLE : WELDING , STRUCTURAL PRODUCTION**

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- o MANUAL WELDING ( MS, HTS, HY80 )  
SHIELDED METAL ARC .
- o AUTOMATIC WELDING  
SUBMERGED METAL ARC ( MS, HTS )  
GAS METAL ARC (ALUM)
- o INSPECTION  
A- NO N.D.T  
B- BASIC N.D.T  
C- FULL N.D.T

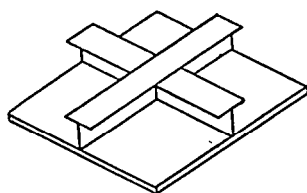
## PLATE & STIFFENER WELDING

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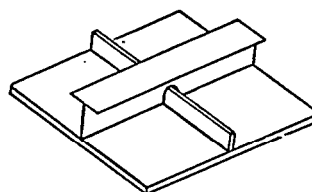


## STIFFENER INTERSECTIONS

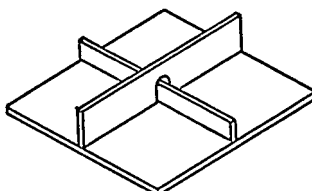
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TEE-TEE



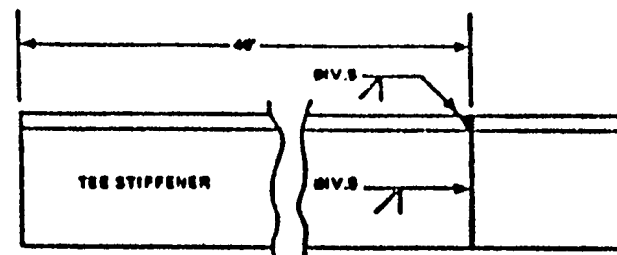
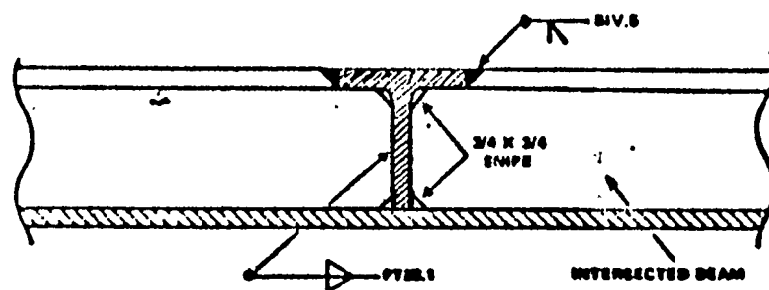
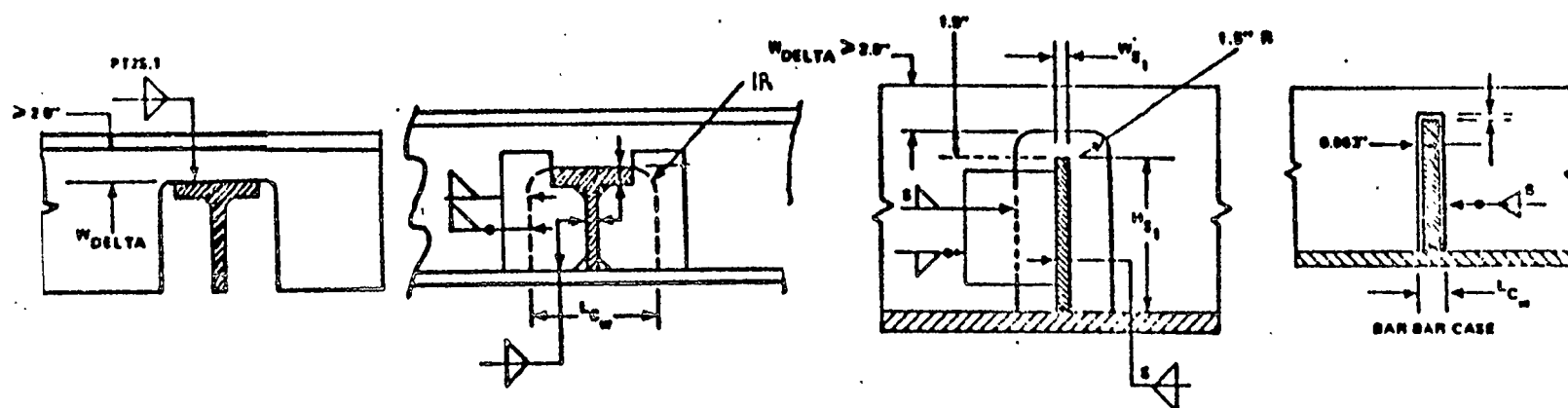
TEE-BAR



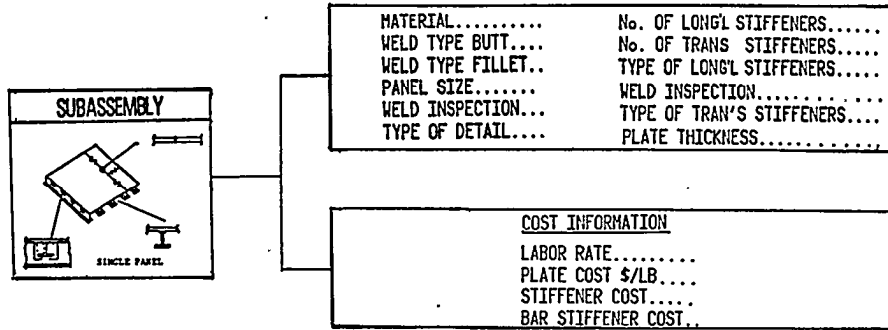
BAR-BAR

## STIFFENER INTERSECTIONS DETAILS

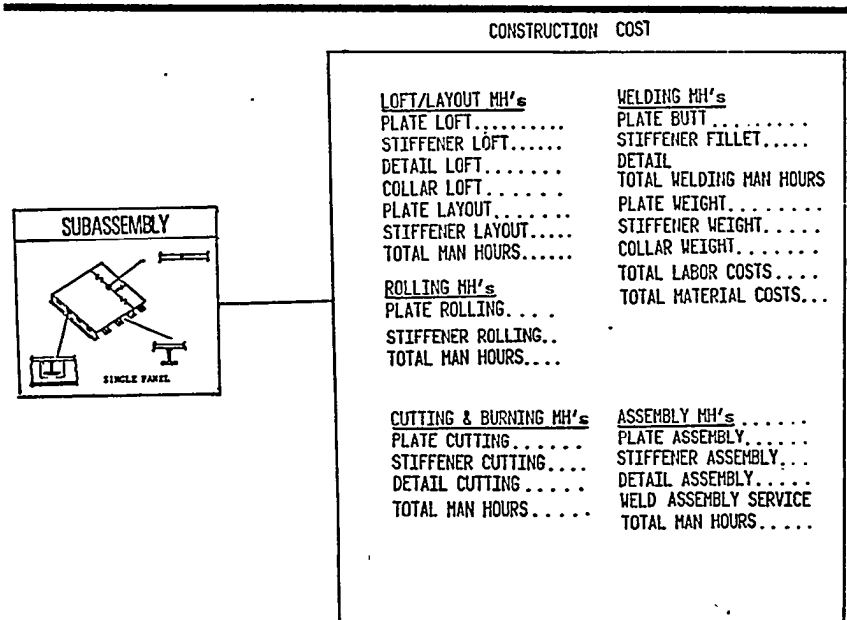
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## OUTPUT - PHASE 1

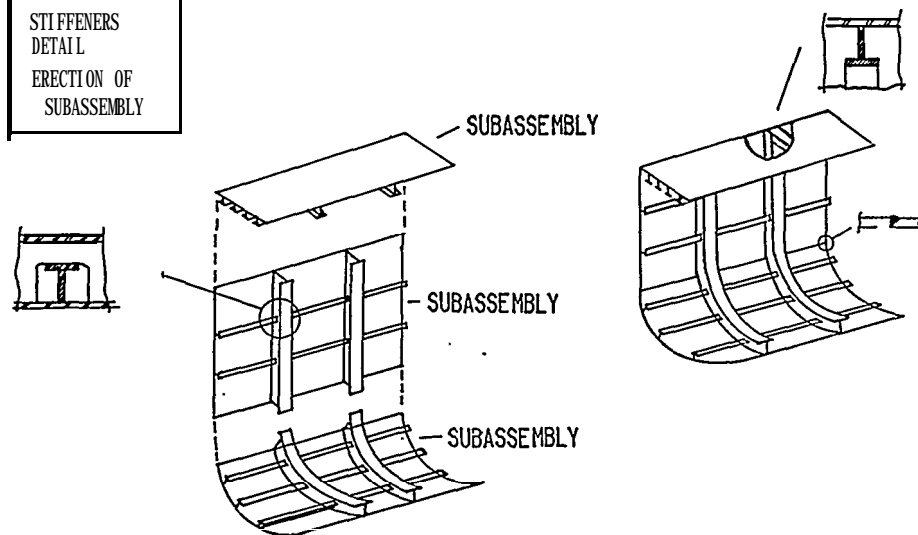


## OUTPUT - PHASE 1



## PHASE 2 - SHOP ERECTION

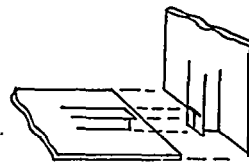
COST INFORMATION
PLATE
STIFFENERS
DETAIL
ERECTION OF
SUBASSEMBLY



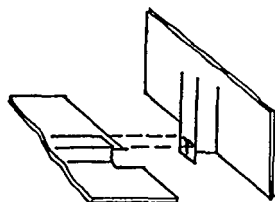
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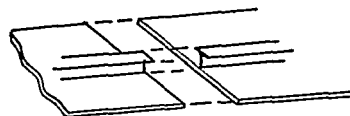
-STIFFENER BUTTED AGAINST  
HATE



- END STIFFENER CUT  
- STIFFENER BUTTED



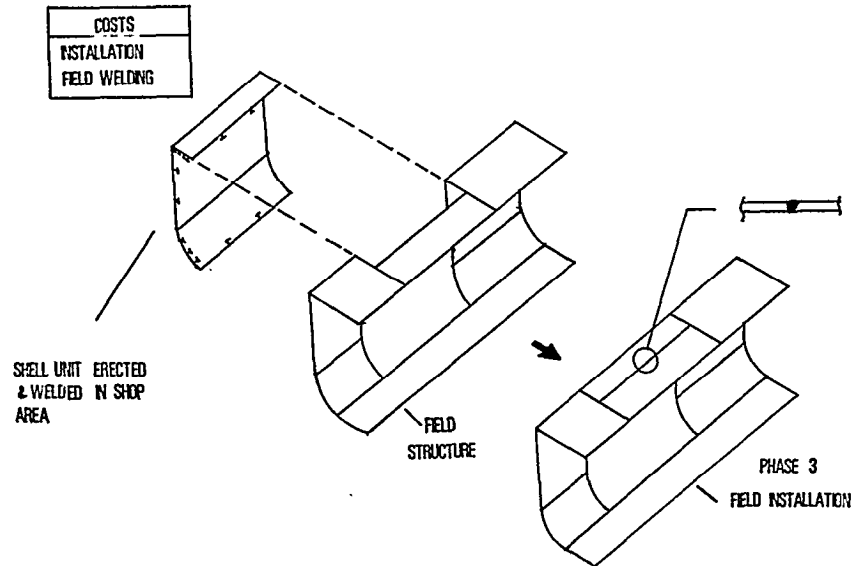
-END STIFFENER CUT  
-cutout PLATE.  
'STIFFENER BUTTED



-STIFFENER BUTTED  
-SAME SIZE

## PHASE 3 - FIELD INSTALLATION

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## ENGINEERED UNIFORM METHODS & STANDARDS

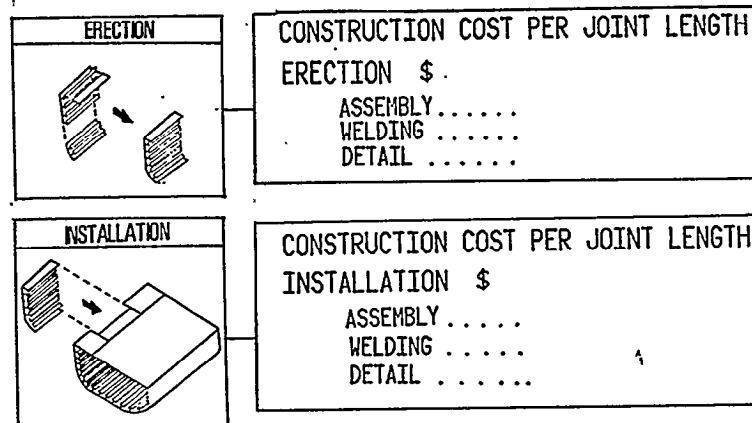
TITLE 1 STRUCTURAL FIELD INSTALLATION

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- O SHELL
- O DECK
- O BULKHEADS
- O STANCHIONS
- O SIDE & WEB FRAMES
- O DECKHOUSE
- O SHELL UNIT
- O BOW UNIT
- O STERN UNIT

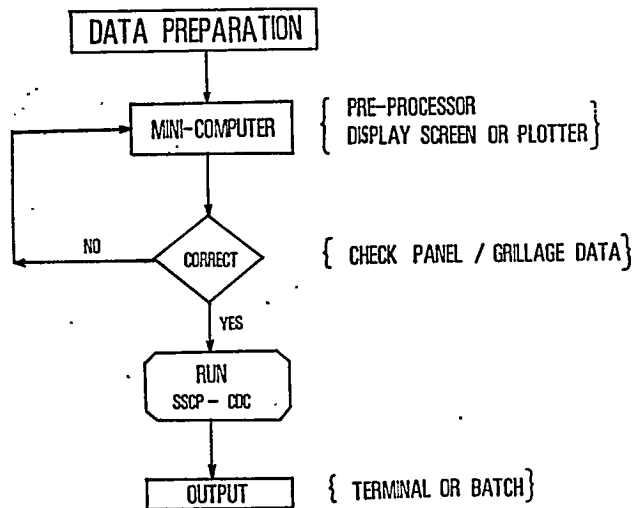
## OUTPUT - PHASE 2-3

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## PROGRAM EXECUTION SCHEME

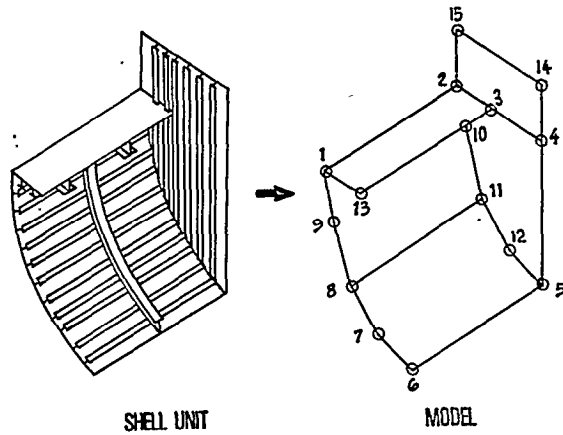
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## COST MODEL INPUT DATA

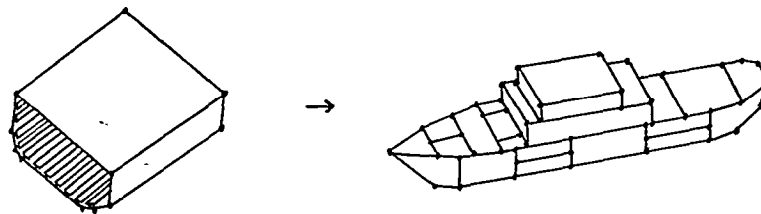
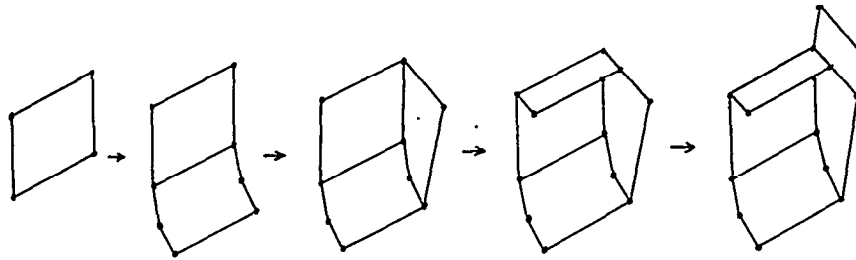
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INITIAL DATA
MATERIAL COST
LABOR COST
PANEL DATA
NODES
GEOMETRY
SCANTLING
DETAILS
WELD INSP.
CONSTR. SEQUENCE
PLATE SIZE CATALOG



## CONSTRUCTION COST MODEL

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## FUTURE WORK

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- AUTOMATED COST/WEIGHT OPTIMIZATION PROGRAM
- DEVELOP COST ESTIMATING TOOL (REPAIR & CONVERSION)  
FOR NAVAL SHIPYARDS

DEVELOP COST ESTIMATING TOOL (REPAIR & MAINTENANCE)  
FOR NAVAL SHIPYARD

## HUMAN PERFORMANCE ENGINEERING: ON REVERSING THE PRODUCTIVITY SLOWDOWN

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### ABSTRACT

In this paper a human performance engineering approach to increased work productivity is outlined. Three applications are summarized by way of illustrating its major advantages and features, one in manufacturing, one in a service, and one in a sales setting. The ingredients of this approach start with a precise statement of desired company objectives in terms of behavior changes that may be required of individual workers. An accurate and reliable behavior counting system is needed next to learn exactly what workers are doing so that graduated steps toward the final behavioral adjustment can be planned. A feedback system in the form of individual, public charting is then to be introduced. Following a suitable period, a potent and relevant positive consequence consistently should be given for behavior increases or for maintenance of an acceptable performance. Various safeguards, tests for effectiveness, and implications are discussed.

There seems little need to document either the fact or the consequences of the post-1967 productivity slowdown in the U.S. to a group that explicitly is dedicated to productivity increase. I assume that each of you know of the catastrophic consequences of this slowdown (coupled with occasional periods of actual decline) for a nation that is founded upon the principles of competition and free enterprise as well as for each and every individual that comprises the population of that nation. Accordingly, I also assume that this audience is chronically vigilant in their search for factors that may address this slowdown. Finally, it is presumed that each of you courageously would experiment with any means that showed promise to "undo" our current attenuated Productivity level. I am here to present to you one such possible "means."

However, a disclaimer may be needed before proceeding further. you should note that I have not been invited to tour, explore, or discuss with anyone the explicit productivity problems that are endogenous to shipbuilding. This means that I have no data from productivity experiments/projects such as we have been gathering elsewhere that directly bears on this important area of manufacturing. Fortunately, I often have presented to groups for which I have not had specific examples and the results have been encouraging. These groups include civil engineers, army civilian administrative personnel, productivity directors in the aerospace, food processing, and petroleum industries, steel foundries, and many, many others. These groups have found that our data and principles readily can be applied to their respective settings and accordingly have sometimes been able to set prototype programs in place! Noteworthy in this connection is the invariant comment from these groups that (1) because of the putatively radical departure in our perspective about human activity from much of what they previously had been exposed to and (2) because

of the seeming pronounced effects that we report, a well-delineated context is needed in order to evaluate and perhaps appreciate the forthcoming information.

In response to this request for a contextual frame, it has been our finding that marked productivity gains often can be achieved through the proper application of a people-change technology. Changes in how people relate to tasks, to their managers, and to their own history qualify here. This paper accordingly is concerned with changes in what, where, when, and with whom people work and how these changes can result in important productivity gains. Opinion surveys from the past 15 years tell us that changing persons may be more difficult now than in past decades, however. Opinion trends within the U.S. work force show that work attitudes likely have undergone precipitous change from those following World-War II and through the late 1960s.

Whereas the majority of the work force purportedly "respected" their managers, "trusted" their companies, and believed that hard work "paid off" during the early post-war period, the majority now appear quite different in these regards. Over 70% of those surveyed feel that they currently can disagree with their supervisors, that businesses in general are untrustworthy and deceptive, and that their labors often go unnoticed and unappreciated. Moreover, the current work force, now more top heavy than ever before with inexperienced youth and females, appears much more likely than in post-war times to voice their opinions, to insist upon input regarding both their own work assignments and company operations, to request participation in decision making, and so on. And, if these requests are not met, evidence is mounting that a majority of workers have learned to subtly withdraw, hold back, and attenuate involvement rather than quit their jobs. All of these apparent differences in the character of our current work force likely reflect the byproduct of the greater

sophistication, worldly perspective, and social awareness that accompanies a higher overall educational level and increased exposure to the multi-modal communications "advances" of the past two decades.

According to the pollsters, one consequence of these seeming attitudinal alterations in the contemporary work force is that old management "styles" and traditions simply will not suffice. These opinion analysts accordingly predict little success for those tradition-bound managers that believe it their job "to give rather than to receive heart attacks," or that they are "the thinkers" and their supervisees are "the workers." This latter "bring-body-leave-brains-at-home" philosophy will not suffice as a means of reconciling today's work force with increased work, company involvement, and with the spirit of challenge that may be needed to reverse the current, disastrous slowdown.

The people-change approach to increased productivity is confronted with yet another problem besides that of a putatively more demanding (petulant?), sophisticated, and jaundiced work force. There are almost as many so-called work-improvement programs as there are organizations that employ them. Moreover, those that champion these programs often have been unusually noncritical in their claims of benefits and values (cf., Cummings & Molloy, 1977), remiss in providing sufficient detail, are short on rationales for the procedures that were used, and often indifferent in the use of rigorous procedural safeguards typically believed necessary for drawing firm conclusions (cf., Campbell & Dunnette, 1968; Goldstein, 1980). Representative of these work-improvement programs include autonomous work groups, organizational restructuring, flexitime, participative decision making, job restructuring, management-by-objectives and goal-setting, task- or interpersonal-oriented team/group approaches, transactional analysis and, perhaps, quality circles.

Although each of these work-improvement programs presume somewhat different "manipulations" or so-called "action levers" (Cummings & Molloy, 1977) for their effectiveness, it nonetheless is possible to discern at least two features that are common to all. First, with the possible exception of the (unmentioned) Scanlon Plan, the aforelisted programs rest heavily upon "antecedant" means to change work performances. By antecedant is meant that various putative non-performance features of the person---such as an internal state, condition, or mental process---must be altered as a prerequisite to work changes. As examples, certain of these work-improvement programs variously are dedicated to increasing "commitment" (the antecedent state) to specified goals, "intentions/convictions" to work harder/longer, positive "feelings" about job and/or company, and so forth. These alleged antecedant-state changes are seen as propadeutic to improved work. They are antecedant in the sense of being precursors to the desired performance.

The second common ingredient of the above-listed programs is that most do not rest upon firm empirical evidence. Actually, evidence of two sorts is needed for the validation of these antecedant-oriented approaches. The first pertains to documentation regarding the alleged change that occurs in the antecedant condition per se. The question of importance is whether such alleged entities as commitment, esprit de corps, job satisfaction, and so forth actually undergo alteration as a result of exposure to the program under consideration. Evidence for this kind of change refers to the internal validity (Campbell & Stanley, 1966) of a program. Unfortunately, there is a paucity of evidence of this sort for any of the above-listed work programs (cf., Cummings, Molloy, & Glen, 1978). Clearly, without firm information of this kind, there would be little value in assessing whether the program under question influences external measures of importance to the organization per se. If internal changes

either do not occur or are not well understood, there is little utility in looking for the *influence* of such changes upon company operations! Yet, the latter is the "proof of the pudding," so to speak. The second question to be answered thus is whether the program *actually improves some* aspect of human .

Again, while there have been many claims that each does, i.e., decreases costs, or waste, or withdrawal, increases productivity, or quality, rigorous evidence is even more sparse in these regards than for internal changes! This latter kind of evidence is tantamount to concerns regarding external validity, and constitutes the sine qua non or foundation that any work-improvement program must have if it is to be a viable option in addressing the present productivity slowdown. Perhaps the most recent testimony as regards these hiatuses in evidence for current antecedant approaches is that summarized by Woodman and Sherwood (1980) regarding the "team" or "groups" approach to work improvement. Their conclusions *regarding* both internal and external validity for the latter are fully consistent with those of the present article regarding most extant work-improvement programs. A final comment here is that even were the evidence both greater and of better quality regarding both the internal and external validity of these approaches, each poses the further untested concern of general applicability. Clearly, any program of work improvement will be of interest to productivity experts the degree to which it readily can be adapted to the manifold work settings that prevail in our complex culture. Unfortunately, many of the above-listed strategies, even if ultimately proven externally valid, seem quite limited in this connection. For example, autonomous work groups and job redesign likely have quite restricted application because of the larger problems they pose for organization restructuring and overhaul, materials handling, and so forth.

### Human Performance Engineering: A Possible Solution?

The people-change approach to work improvement espoused in this report rests upon an entirely different information base than the above-listed strategies. In order to appreciate the potential value of this programmatic approach, three projects are summarized in varying detail below. These were selected because (1) each represents an application to one of the three major divisions of human work (sales, service, and production), (2) each repetitiously illustrates the basic ingredients of this approach, and thereby, the broad applicability it may have for bringing about work changes regardless of setting, work population, or business endeavor, and (3) they provide a solid basis for the conclusion that its major ingredients can be guaranteed to work when properly implemented. Thus, following an exposition of these three projects, the step-by-step ingredients that should be followed in any performance-engineering project "package" will be outlined as a technology, the underlying theoretical basis for each will be revealed, and why these ingredients always work will be discussed.

#### Project one: Human performance engineering in a manufacturing setting.

This project was undertaken because one of two major plants of a medium-sized, midwest, furniture manufacturing company consistently reported an earned ratio that was considerably less than the plant located in the deep south. The earned ratio (expressed in terms of standard hours required to turn out the finished product/actual hours expended) was a mediocre .54 for the target plant and a laudatory .67 for the southern setting. Individual worker efficiency was targeted for modification as a remedy for this deficiency in productivity. An appropriate individual, daily measurement system already was in place in that each worker filled out a card designating exactly what they had done and the time frame involved. These scores were collected by



respective supervisors and submitted to the computer for conversion into average daily efficiency indices. Most workers thus understood the meaning of their efficiency measure, and that it reflected actions that directly were under their control. The overall project design involved preplanned department by department introductions of the ingredients of the performance-engineering program. These ingredients included systematic involvement of each level of plant management, including the plant superintendant. Program features within any given department included (1) collection of individual average efficiency indices, their register on 8-1/2 in x 11 in specially-designed charts, and their study without worker or supervisor awareness for a minimum of eight weeks. Next (2), each individual chart was publicly posted in a conspicuous place and kept updated (by the department supervisor) by a.m. posting of the previous day's efficiency index. This procedure was followed for a minimum of eight weeks, and sometimes quite longer.

In the meantime, (3) supervisors received extensive training on the charting procedure, on learning emotional neutrality during the initial display period (baseline), and on how to praise and provide positive social supportiveness when efficiency either increased or was maintained at near 100%-of-standard level. This procedure of (1) covert charting, (2) neutral public display, and (3) efficiency-contingent supervisor supportiveness was augmented by (4) bringing on the second-level supervisor. (S)he in turn participated in a charting endeavor to publicly and daily display the percent of completed charts by respective supervisors. In addition, second-level supervisors aperiodically administered a behavior-rating scale to workers to obtain a "positivity" score for individual supervisors. These scores also were publicly posted. Both the second-level supervisor and plant superintendant were trained to dispense social support to those first-level supervisors that kept their supervisee charts up to date and who achieved "high" positivity ratings.

These program ingredients initially were introduced into the Fiberglas department wherein various of the program ingredients were perfected. During this period, overall department efficiency markedly increased, and subsequently has been maintained (three years to date) as shown in Figure 1. Then, on a temporally-staggared basis, these ingredients respectively were introduced into the upholstery, punchpress, welding, plating, polishing and buffing, packing, and mainline departments with successes ranging from modest but statistically reliable increases (upholstery department) to increases that were so marked as to not require statistical analyses for verification (all other departments). Some of these data are displayed in Figures 2-4. The efficiencies of the three lowest and three highest performers were averaged over departments and compared with the intermediate performers at each program point; namely, baseline, feedback, feedback plus praise and followup. These data, shown in Figure 5, clearly reveal uniform program influence across all individuals within and across departments.

The design of this project was multiple-baseline in nature and thus permitted conclusive revelation of the effectiveness of each program ingredient. In effect, each department was a separate replication that showed that only when charting (feedback) and/or charting plus praise was introduced, efficiency increased. This is clear evidence of internal validity for this work-improvement approach. External validity is shown in Figures 6 and 7 that respectively reveal overall plant efficiency and earned-ratio increases over the tenure of the program as thus far undertaken. Overall, efficiency has risen from 84% to 96+% and the earned ratio from .54 to .665. Moreover, these gains nicely correlate with efficiency changes in individual departments.

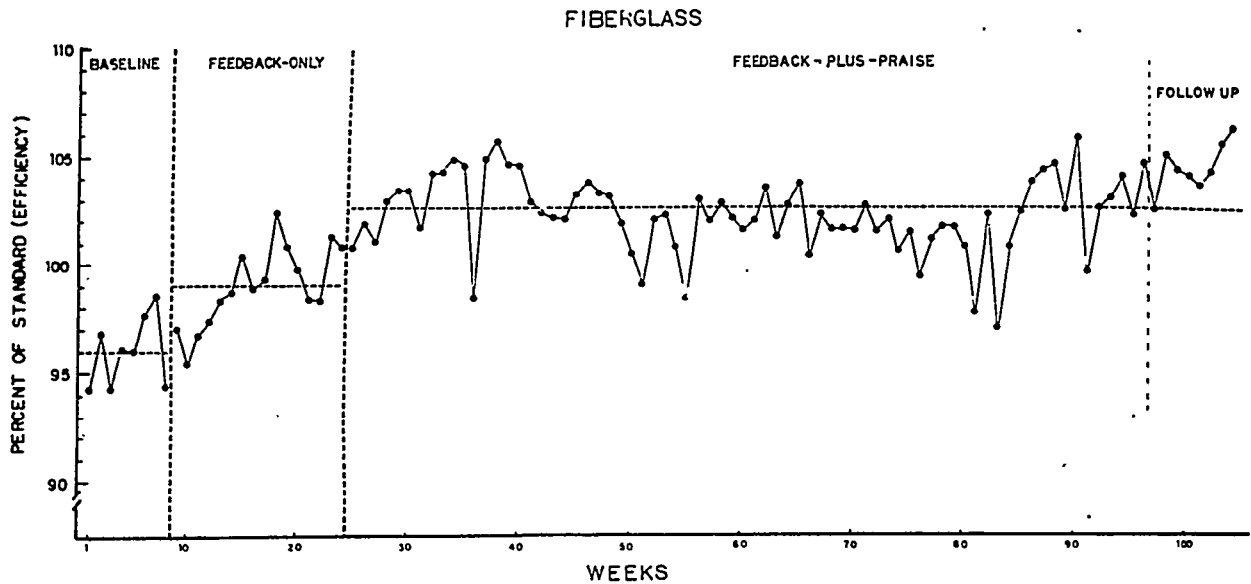


Figure 1. Average weekly efficiency of the Fiberglass Department. The initial 8 weeks (baseline) depict department efficiency prior to introduction of individual charts (collected during the latter months of 1977). The next portion of the graph shows the mean efficiencies for the first and last 8 weeks for public charting per se (feedback-only); the next section depicts mean efficiencies for the next 72 weeks during which performance-contingent supervisor praise was added to the feedback procedure; and, the last portion represents an 8-week block sampled in the Spring of 1981 in order to show perseverative program effects. This portion simply reflects the effects of continued feedback and praise.

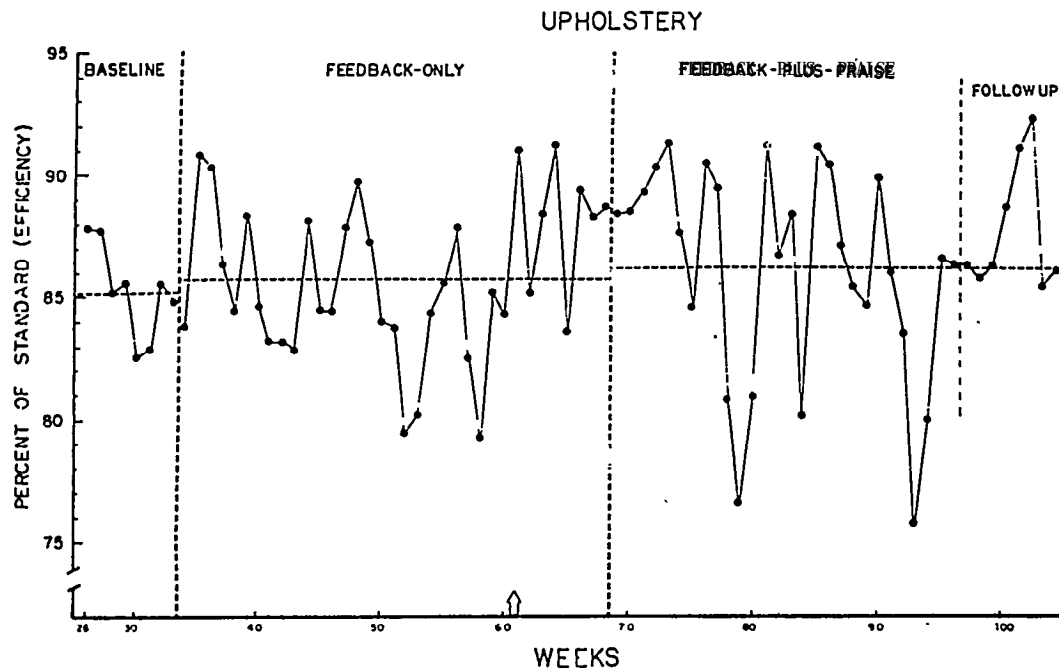


Figure2. Average weekly efficiencies of the Upholstery Department. The feedback portion of the program was applied to this department several months after the feedback-praise intervention was introduced into Fiberglass. Otherwise, legend applications are the same as for Figure 1.

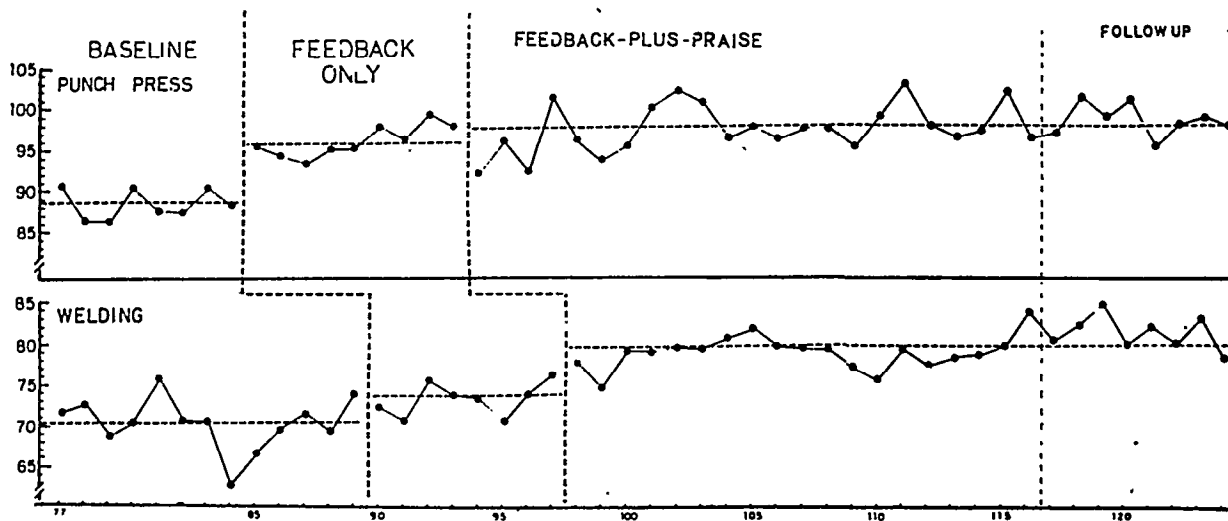


Figure 3;. Average weekly efficiencies during temporally-staggered program introductions into the Punch-press and Welding departments. Chart display for Punch Press occurred well after the feedback-praise intervention in Upholstery. Legends are the same across figures.

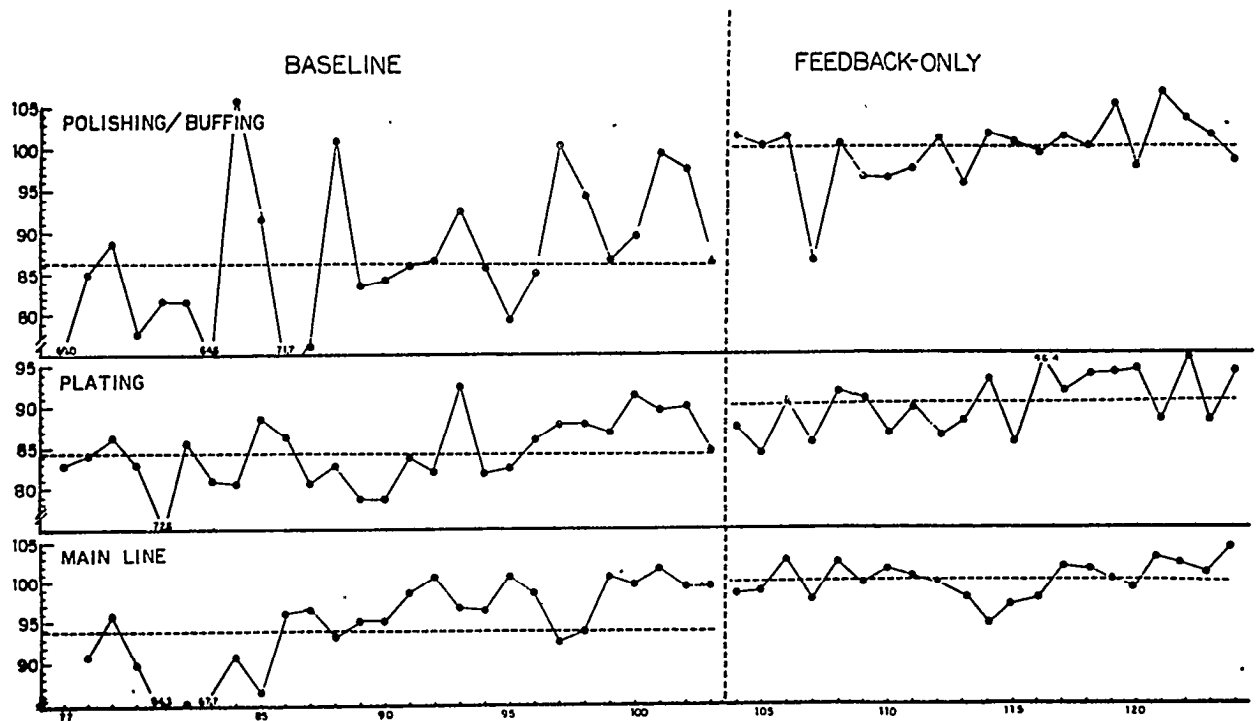


Figure 4. Average weekly efficiencies during program introductions into the Polishing-Buffering, Plating, and Main Line departments, all initiated after the Welding program. Legends are the same across figures.

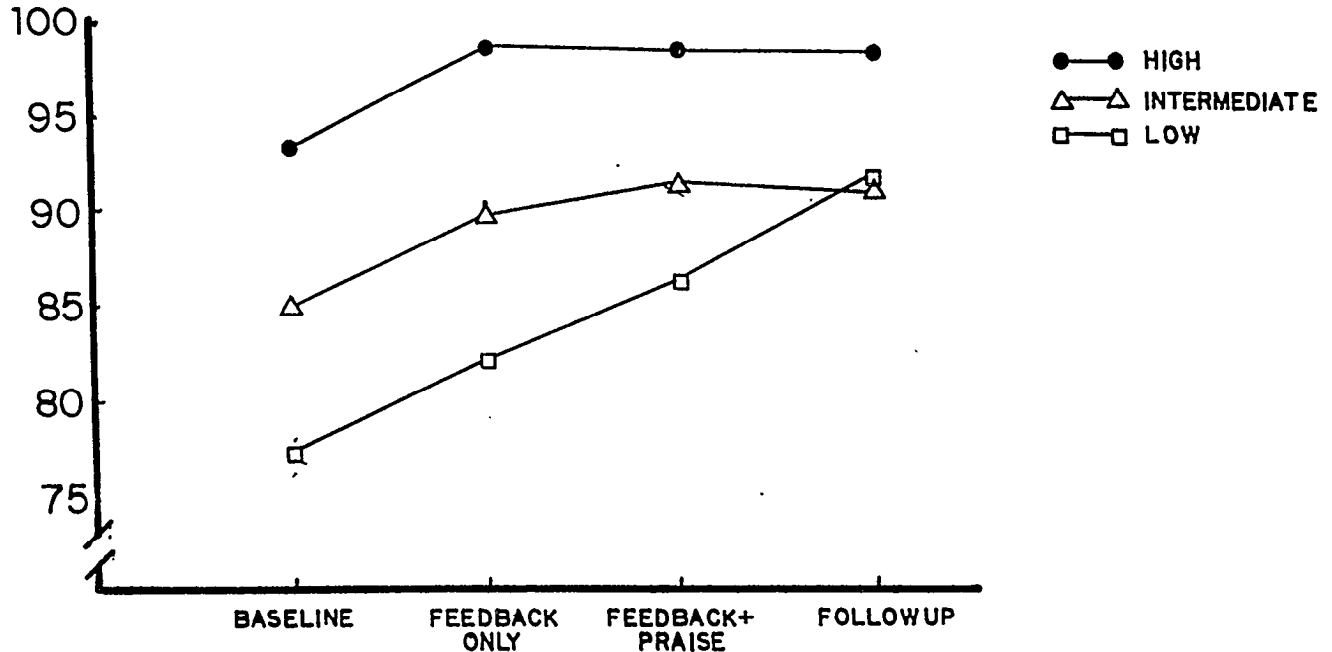


Figure 5. Mean Efficiencies, averaged over seven departments, for the 3 lowest, 3 highest, and remaining intermediate performers (determined from baseline efficiencies) for the respective baseline, feedback-only, feedback plus praise, and followup program phases.

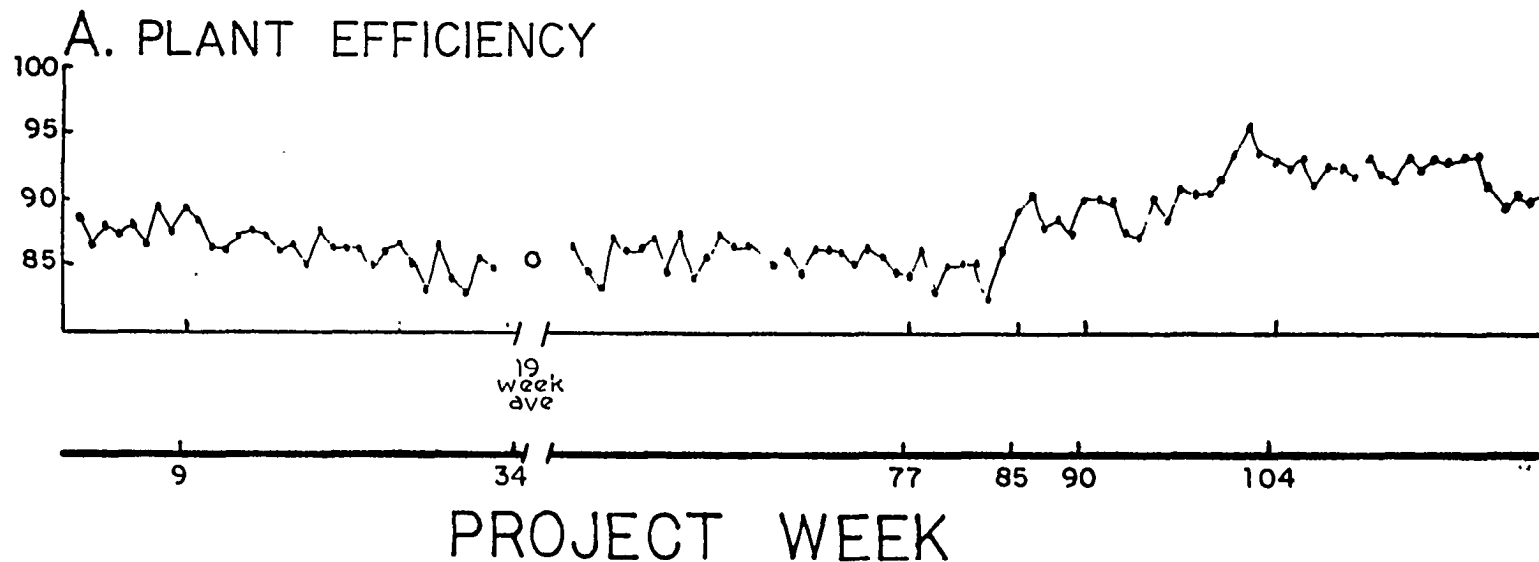


Figure 6. Overall weekly plant efficiencies over the tenure of the work-improvement program (as of February, 1981).

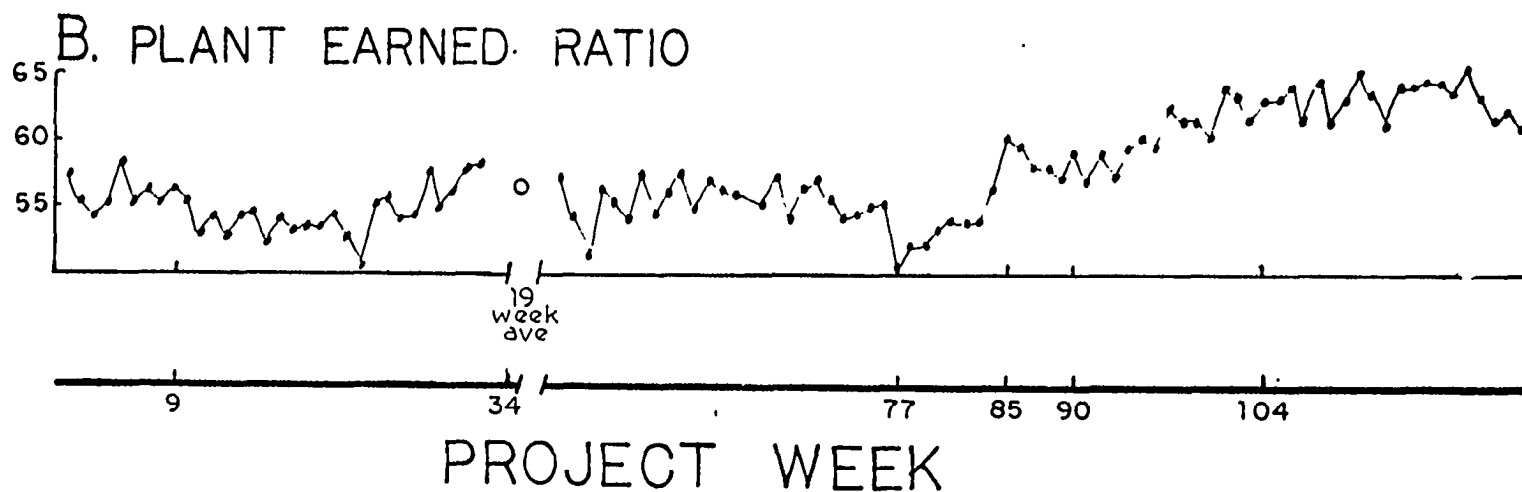


Figure 7. Overall earned ratio over the tenure of the work-improvement program (as of February, 1981).

Thus far, this program successfully now has been extended into various corporate office operations, truck delivery, and most recently to the sales operation. The successes therein have been comparable to those reported for the target factory.

Performance engineering in the public accommodations industry: Better services for increased patronage. Our work in the public accommodations business began in 1973 in a large, 900-plus room, downtown hotel in a major rocky mountain city. The problem addressed was how to get room attendants to clean rooms to a much higher standard of cleanliness. Over 100' attendants and approximately 18 supervisors were involved in this undertaking and, while less than elegant, we were able to achieve this goal within a six month period using an adaptation of the human-performance-engineering approach. Shortly thereafter, we had an opportunity to refine, formalize, and extend the procedures of this preliminary undertaking by adapting our program to address an exceedingly unclean, large, 550-room convention hotel located in the center of a large midwest city (Anderson, Sponsel, Clarke, Brence & Crowell, 1977; 1978). The rooms aptly can be characterized as very unclean at that time, and an outside firm estimated \$25,000 (adjusted to the 1981 dollar) to remediate this condition on a one-time-only basis.

The program began by constructing a 70-point checklist that covered in minute detail all facets in need of cleaning for a prototypical room. Initial level of uncleanliness was assessed through application of this checklist to 50 randomly-selected rooms by the executive housekeeper and two assistants who had been carefully trained to accurately and reliably apply this measurement device (85+% agreement among scorers). Additional random room ratings were obtained on this list at key periods throughout the remainder of the program in order to gradually increase behavioral demands for deep cleaning from the

attendants, the list was divided into three components. Each conformed to different portions of a room. The first (and most difficult) consisted of the 21 points that applied to the bathroom tub and tile areas. Nine supervisors then were reliability trained to use this sublist (three weeks of individual daily charting, discussion, and training of percent-agreement scores with the head housekeeper). Daily reliability checks on unspecified rooms for each supervisor continued throughout the program, and are averaged for the first and last 10 checks of each program component in Figure 8. As seen, all evinced marked improvement in agreement percentages with this list over initial training trials, and then maintained a high agreement average thereafter throughout all portions of the program.

Room attendants then were requested to choose a bathroom from the 15 that each regularly and daily were assigned, and given a maximum of two consecutive days to achieve a score of 18 or better. These scores publicly were charted. In addition, covert (unknown to attendants or supervisors) room checks were conducted randomly during this period on untargeted bathrooms. A reward contingency was introduced after the sixth week of charting. Credits in the form of points were given for scores that achieved 18 or better (such a system has been defined as a token economy). A similar point system was used for supervisor reliability scores. Credits were exchangeable for weekly meal tickets, popular trade stamps, time off with pay, or a meal for two at one of the hotel's expensive restaurants.

All bathrooms achieved a score of 18-21 points within three months of program inauguration (preprogram baseline was 5.5 points). The program then was suspended for 30 days during which random rooms were again assessed (without the knowledge of the attendants or supervisors). Scores declined to an average of 15 points for this period. Fourteen checkpoints then were



Figure 8. Mean percent agreement scores between supervisors and the executive housekeeper. The first 10 scores reflect the changes that took place during the training period. Thereafter, scores are for the first and last 10 rooms cross-checked between supervisor and executive for each program stage and phase. Stage one conformed to room cleaning with the 21-point list, Stage two with the former plus an additional 14-points, and Stage three with the latter and yet an additional 35 points (70 point checklist in all).

added to the first 21 and the credit (token) system changed so that tokens were given for scores of 33 or better. Covert room and daily reliability checks for supervisors continued. All rooms achieved 33 points or better within another three-month period. Following another brief program suspension during which unannounced room checks again were made, the remaining 35 points were added, and the third stage was inaugurated with the full 70 point checklist. In effect, this gradual addition of checklists leading to the 70 point standard exemplifies a major aspect of the human-performance-engineering undertaking, termed behavior shaping. Shaping thus represents a way of gradually upgrading requirements while taking into account the initial skill level of the employee.

Stage three lasted four months, followed by another withdrawal and assessment period. Finally, a maintenance program was introduced that entailed continued charting, tokens for scores of 65 or better, and the requirement (agreed upon by attendants) of a minimum of three rooms completed per week. This continued off and on for the next four years. All rooms were maintained at the 65-point-or-better average as long as the program was in place. Whenever temporarily withdrawn, scores declined an average of 19 points.

These data are illustrated in Figure 9 as a time-ordered, multiple-baseline (changing criterions) design. The upper graph of this figure shows, respectively, average points on the 21-point list prior to program inauguration (p), over the first five rooms (I1), on untargeted rooms (T, hatched area), over the last five rooms (I4), and during program withdrawal (W) for Stage One, and for consecutive first five rooms, untargeted rooms, last five rooms, and withdrawals for each stage thereafter. The data for the next 14 points on the list that covers the rest of the bathroom are detailed for respective stages in the intermediate graph of Figure 8, and the data for the remaining 35 points

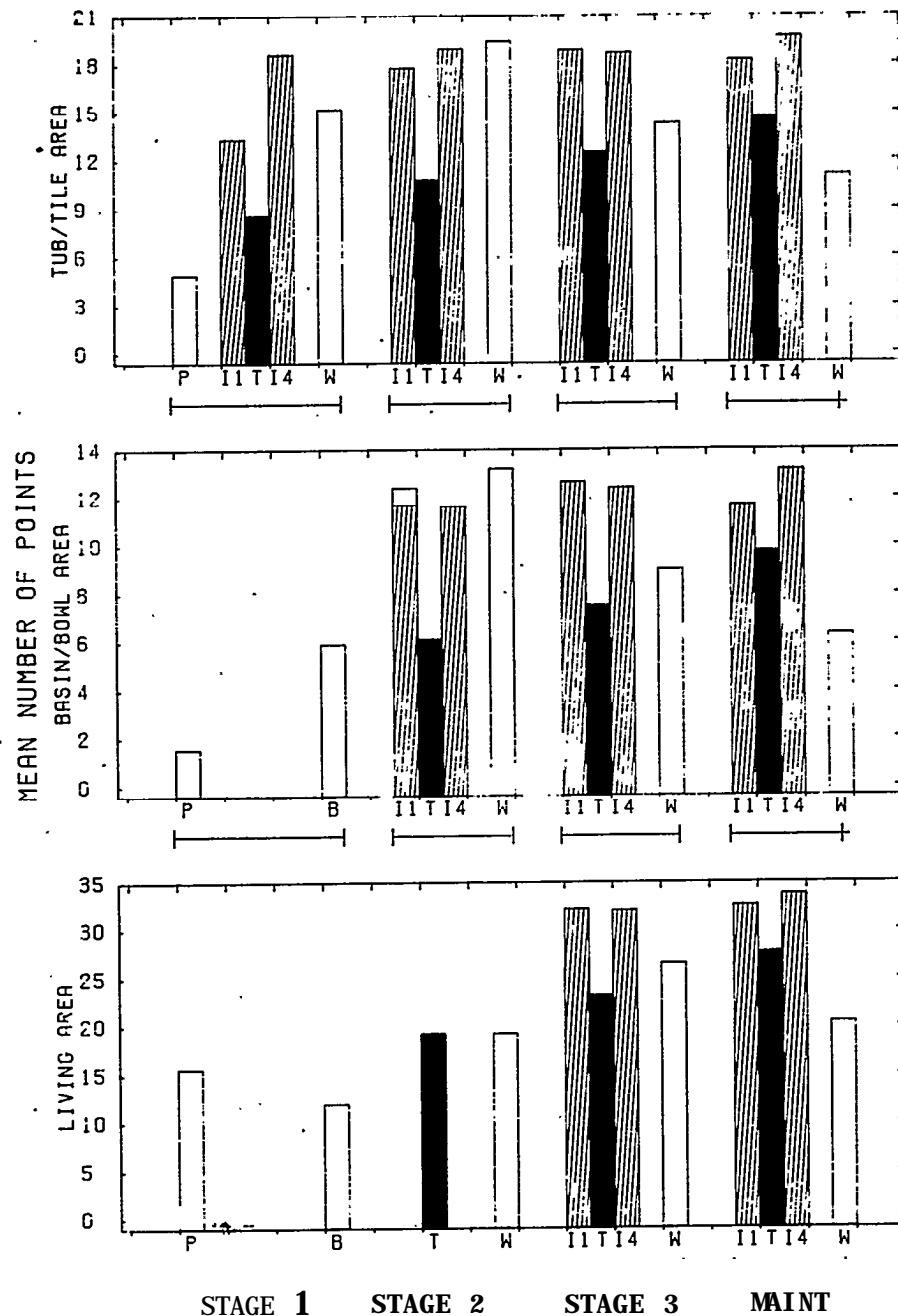


Figure 9. Mean checklist scores, averaged across room attendants, for various checklists and program stages. P designates preprogram baseline, II and 14 the initial and last 5 rooms of a program stage, T the score on untargeted rooms, and W the score following temporary program withdrawal. Maint refers to the maintenance program

for respective stages in the lower graph. The temporally-staggared (time-ordered) introduction of each program component also is shown by the different onset of respective lists. Note that marked performance improvements do not occur for any list until its formal introduction as part of the program. There is some evidence, however, of modest "spillover" effects to parts of the room untargeted for change from program influences already underway.

This project can, in several respects, be viewed as a model work-improvement program that rests upon the technology of human performance engineering. The program ingredients of three stages (behavior shaping), daily charting for both attendants and supervisors, ongoing reliability measurements, a token reward system, multiple baseline and full program withdrawal procedures, and complete pre- and post-stage data collection periods that reflect dramatic increases in and maintenance of room cleanliness illustrate how an applied human-engineering technology can effectively increase productivity through strengthening those actions that are pivotally relevant to task outcome. The basic features of this program subsequently were extended to the housemen in charge of cleaning all restaurants and public areas as well as to bellmen and various other personnel within the hotel. Finally, variations of this procedure now have been introduced in other properties of this company, including in Scottsdale, Ariz., Chicago, Ill., Detroit, Mi., Danvers, Mass., and Nashville, Tn.

While I originally intended to present an application of this technology to the sales arena of human work, time and space do not permit. As noted in the presentation, the application chosen here was a real-estate firm that employed the most agents in their "corner" of the state but that only ranked seventh in total dollar volume. Suffice it to say that the application of this technology reaped handsome benefits, including an increase in dollar volume

sufficient for an increase in ranking to Number One while the program remained in effect (cf., Anderson, Crowell, Sucec, Gilligan & Beles, 1978).

### Conclusions

There are a number of important features to discern from the preceding projects. First, quite different work populations were involved, ranging (a) from manufacturing to service/sales, (b) from the educated to the relatively unskilled, and (c) from those that resided in large metropolitan areas to those who lived in a mostly rural area. Second, all were conducted during this most recent period when the so-called slowdown in productivity has been at its zenith. This period can be characterized in numerous ways, including (1) as a time in our history following the end of the migration of the farm worker to the city, (2) when union power has been at its greatest, (3) after the "baby boom" has entered the work force, and (4) along with an all-time high proportion of females, (5) when inflation has reached near-record levels, (6) when federal regulations have been their most costly and restrictive, and so forth. In spite of these factors, these projects have in common marked and durable productivity increases that can be directly attributed to a programmatic increase in relevant work behaviors by individual workers.

The reason for this across-board productivity increase is, I believe, conceptually straight forward. Managers were enlightened with principles and techniques consistent with the 1980s; but fully different from those of the past. Those persons then were supervised in the implementation of these techniques until relevant adaptations were complete. Moreover, both manager and front-line worker alike were and remained long-run participants in the behavior-change undertaking. In addition, the techniques that each employed were themselves conceptually easy to grasp. Each entailed, initially, a definition of respective productivity goals in behavioral terms. For the

furniture manufacturing project, the behaviors targeted for change were number of pieces per unit time. For the hotel illustration, the behaviors were defined in terms of number of checkmarks. And, for the sales example, the behaviors were number of initial and personal, face-to-face client contacts.

Second, behavior measurement systems were established that were accurate, reliable, and unobtrusive to apply. Such was already in place in the furniture example in the form of worker-administered, work-record sheets. Supervisor-applied checklists constituted the measurement strategy for the hotel example, and self-administered record sheets consisting of factual customer information constituted the measurement procedure for the sales illustration. Ways to uniformly collect, collate, and individually record this information were devised in each instance as well. Third, these data were displayed in chart form, sometimes in public and sometimes not for a while. (Preferably, individual performance data should not be displayed for a period of time in order to locate trends as well as to discern whether public introduction per se results in a beneficial behavior increase.) A rule of thumb here is that the introduction of charts, when done without threat or potential censure, will almost always precipitate a beneficial behavioral increase.

Fourth, rewards were located that (1) were potent and relevant to those designated to receive them, (2) that did not "tax" either the company's or manager's resources, (3) that were easy to dispense, and (4) that did not satiate easily. Once the effect(s) of public charting appeared to level off, the reward(s) were introduced only for desired performance increases or for maintenance of acceptable work activity. And, efforts were made to ensure that rewards were not given at any other time. This fourth prescriptive ingredient is predicated upon the established behavioral law that pleasant

consequences increase the likelihood of repeat behaviors. An important supplement to this law is that if positive outcomes occur independent of a behavior, then that response ultimately will disappear from the response repertoire of the worker. We invariantly have discovered that dispensing rewards in terms of charted changes, one can be assured of consistency, accuracy, and longevity of the program. We also have found that the easiest (and often one of the more potent) reward to employ is social supportiveness. However, the proper usage of this category of consequences requires a good deal of training and practice.

Fifth, procedures were used that permitted an assessment of whether or not any changes that resulted occurred because of the above-itemized procedures and not something else. Brief program withdrawal, multiple-baseline, changing criteria, and so forth were examples of proper assessment strategies for a human performance-engineering program. And, as noted in preceding illustrations, these procedures were applied in a way that supported incremental, step-by-step performance changes rather than massive, wholesale behavioral alterations.

A final note. I began this paper with the assertion that our principle efforts to increase productivity rested upon the application of a unique people-change, work-improvement program. In fact, this depiction is not quite accurate. What has been briefly enunciated in this presentation is instead a behavior-change rather than a person-change approach. This distinction between persons and behavior is made because of our view that people do not seem to have changed much over time. In broad perspective, their needs, aspirations, and goals of today appear much the same as those of our forefathers. However, both the manner by which to obtain fulfillment and the expression of these goals and needs clearly has changed over generations. In

effect, it is our contention that to obtain goals and need fulfillment does not necessitate people-changes so much as behavioral adaptations. The major premise of this paper, then, is that changing people is basically a straightforward undertaking. It is based on the presumption that people do not actually change but that behavior both does and must if we are to adjust to our changing surroundings.

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## PRODUCTIVITY NAVY STYLE

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### ABSTRACT

Productivity improvement is a most difficult concept to come to grips with in the operations of a central, national government. The term "productivity improvement" is most generally considered to mean the beneficial results of acts of innovation or change which are undertaken for the purpose of producing a greater output from a given input of resources. To some, this concept represents the very antithesis of bureaucracy, since it is claimed that by nature bureaucracy is growth prone and resistant to change. This paper describes a productivity program which is being implemented within the Navy industrial base. Three years of successful experience have shed considerable light on the management of change in large military organizations with a rigid institutional structure. The paper draws attention to major dimensions of the Navy's program and to the process of managing for productivity improvement.

New technology, the rising cost of production, and expectations that work should be enriching as well as profitable are causing transformations in the Navy. Traditional tools of economic management are being reassessed as they demonstrate diminishing ability to promote long-term economic improvement.

Created in 1978, as a reflection of growing management concern, the Navy's Productivity Program establishes the framework for improvement. A network of productivity principals has been established in higher echelon Navy and Marine Corps commands with a Director of Productivity Management located in the Navy Secretariat.

Under the direction of the Chief of Naval Material, Admiral A. J. Whittle, Jr., the Naval Material Command (NMC) has established a Productivity Management Office with a cadre of professionals representing the various disciplines attendant to a functionally integrated Productivity Enhancement Program (see figure 1). Although the Navy Productivity Program encompasses all military and civilian organizations, the NMC organic industrial community is the focus of current planning. Corporately, this community employs over 100,000 civilians and involves a budget of more than \$6 billion.

Targets of Opportunity. The Navy Productivity Program, as presently structured, explores three major areas of opportunity. These are: technological advancement, organizational development, and process management.

Technology. Productivity improvements derive from changes in production, methods materials and machinery which in turn stem from the accumulation of scientific and technological knowledge. The technology factor has been credited with at least 40 percent of the growth in productivity over the past five decades of domestic industrial experience.

The thoughtful integration of beneficial technology to the Navy's industrial base represents a critical dimension of the Productivity Enhancement Program. To a very large degree the process is limited by the capacity of the organization to accommodate innovation and to handle uncertainty.

To create a climate which encourages technological venture and innovation, a number of funding mechanisms have been introduced; these include:

a. Cost of Ownership Reduction Investment (COORI) Program. Established as a part of Navy's FY-82 budget planning, this program creates a \$50M funding target to support high payback capital investment opportunities. Candidate projects are placed in competition by operating managers during budget planning (approximately two years before budget approval). Ultimately, the amount of funding (set at approximately \$50M for FY-82) is determined by the quality of candidate projects and a subjective comparative assessment of the relative merit of COORI vis-a-vis other programs in competition for budget funds.

b. Fast Payback Program. The Fast Payback Program is designed to create a funding mechanism through which managers can fund high payback projects with short lead time provided the projects satisfy the following criteria:

1. The project costs less than \$300,000 (\$100,000 non-NIF).
2. The project has a payback of less than 3 years (2 yrs. non-NIF).

Funds are made available to support the Fast Payback Program through two funding mechanisms. These are:

1. Naval Industrial Fund (NIF). Naval Shipyards, Air Rework Facilities (NARFs), Public Works Centers (PWCs) are among many of the Navy's industrial organizations which are NIF funded. Under this funding concept, "earnings" are credited to an industrially funded activity by charging fleet customers for goods and services rendered. Contractual relationships between these organizations and weapons systems custodians (fleet customers) involve fixed price bidding and cost accounting practices not uncommon to those found in the private sector. NIF managers deciding to invest in beneficial technology which qualifies under "fast payback" criteria do so using industrial funds. Costs associated with the investment are amortized by the stream of dollar savings which accrues from the investment. Additional savings, above and beyond the investment cost, are reapplied to enhance the productivity of the organization.

2. Procurement Funds (OPN). A \$3M per year fund is created as a part of the Navy budget to allow non-NIF activities (hospitals, training agencies, headquarters, etc.) to have access to the "fast payback" program. The modest funding level creates intense project competition and safeguards against speculative ("wish list") project submission.

c. Manufacturing Technology (MT) Program. This program explores the application of emerging technology to (1) reduce procurement and life cycle costs, and (2) increase productivity. The program reduces the risks associated with new technology exploration by providing "seed money" to MT program participants. The impact of technology on weapons system procurements costs is impressively demonstrated by a recently completed MT project involving search radomes which are in common use on ship-borne and land based radar systems. In this case, the MT project found that radomes fabricated from foam filled fiberglass may be substituted for search radomes conventionally manufactured from honeycomb structures. The use of foam filled fiberglass reduced the cost of the search radome from \$6,000 to \$450. Projected net savings from this project thru FY 1985 exceeds 5.2 million dollars. (The total cost of the MT project was \$116,000.)

d. OSD Sponsored Productivity Enhancing Capital Investment Program. In addition to the above Navy funded programs, OSD, starting in FY 1981, established a "grant" fund to underwrite the cost of certain productivity enhancing capital investments. To compete for these funds (FY 1981--\$105 Million; FY 1982--\$110 Million), services respond to an OSD PECI "project call" by submitting projects meeting the following basic criteria.

1. Minimum investment cost \$1 Million (modified to \$300,000 for FY 1982).

2. At least 50 percent of economic return of invested funds must accrue from labor savings.

3. Maximum Return on Investment--4 years.

4. Internal Rate of Return--at least 10%.

The Decision Model contained in figure 2 depicts the relationship which exists between the various funding mechanisms which provide access to productivity enhancing technology. It must be kept in mind that technology transfer differs from ordinary scientific information transfer in the fact that to be transferred, technology must be embodied in an actual operation of some kind. Decisions to adopt new technologies are basically investment decisions; they involve elements of risk and uncertainty. Organizations vary in their capability to accommodate uncertainty as a reflection of their value systems, social structures and/or culture. These elements are brought into focus in a second major target of opportunity of the Navy's Productivity Program.

Organizational Development (OD). The importance of the internal organizational environment for the success of any productivity enhancement endeavor is emphasized in the literature and attested to by successful managers. The Navy's OD program provides the structure to recognize and pursue opportunities to strengthen the organization and influence the quality of member behavior. A number of specific programmatic initiatives and accomplishments follow:

a. Performance Contingent Reward System. An incentive program designed to improve individual productivity was developed by the Naval Personnel Research and Development Center and implemented in the data entry section of a data processing center at the Long Beach Naval Shipyard. The employees participating in the study were Navy civilian key entry operators. Production standards were developed based upon keying speed and the amount of time spent working. A Performance Contingent Reward System (PCRS) was designed in accordance with sound behavioral principles and federal guidelines such that a monetary bonus was awarded for high individual productivity. The amount of the reward was directly proportional to the amount of work exceeding a production standard.

Production for the 12-month period improved substantially. Excessive overtime and a heretofore perpetual backlog were virtually eliminated (see figures 3 and 4). The workforce decreased in size but not in productivity as a few employees left the organization through natural attrition and were not replaced. A rigorous cost-effectiveness analysis showed that the set-up costs of the program were recovered in the first three months of operation. A similar follow-on study was conducted at the Mare Island Naval Shipyard with comparable results.

Implementation of PCRSs at other Naval Shipyards has shown that where the basic tenets of a PCRS exist (viz. regular performance feedback, timely reward, and reasonable time-on-the-job standards) significant increases in productivity may be expected.

b. Quality Circles. Quality circles are small groups of workers who get together voluntarily on a regular basis to solve everyday work problems that cause frustration, hurt quality and hinder productivity. Participation is voluntary and meetings take place on "company time." At the last count, there were more than sixty quality circles in the Naval Material Command; the number is growing weekly. Circles engage the talents of machinists, electricians, sheet metal mechanics, engineering technicians and others. They normally meet once a week for an hour, accomplishing their regular week's work in the remaining 39 hours.

The idea of soliciting worker expertise is, of course, not new: witness the suggestion boxes installed--and often covered with dust--at many work sites. What the quality circles offer is a structured means of combining workers' practical experience with the analytical approach of the manager, and a formal channel for proposing solutions of management.

A key to the success of circles in the Navy is that participation is voluntary for both managers and workers. The result is genuine enthusiasm, as well as growing appreciation and understanding among the people involved.

The quality circle concept has an added advantage in that it requires little or no change in existing organizational structures. The circle method is a relatively simple technique that can be used in any work situation. And both workers and management benefit when work-related problems are solved in the circle.

When the project was undertaken at Norfolk Naval Shipyard, whose 12,000 employees make it the second largest employer in Virginia, shipyard unions showed their support by filling positions on the steering committee that directs the program.

For every dollar invested, quality circles have saved the Norfolk Naval Shipyard \$3.75. The net savings, after deducting all costs of operating the program, including staff time and travel, were \$150,000 in the first year.

c. Productivity Awareness. The media today are responsible for a significant elevation in the level of social consciousness associated with productivity. Officials in labor, management, academia and government appear to agree that productivity must improve if our nation is to remain economically and socially sound. These factors when coupled with the many emerging productivity issues coming from the world of work plus ever-present changes in management methods, structures, priorities and personalities establish the basis for a productivity awareness program.

Under the sponsorship of the Director of Productivity Management and the Naval Material Command Productivity Management Office, the following initiatives are being pursued:

1. Prospective Commanding Officers (PCO) Course. Commanding Officers (COs) of naval field activities are subject to rotation at regular (nominally 3 year) intervals. The Prospective Commanding Officers Course is structured to equip all expectant COs with information on programs of contemporary interest prior to their assignment. The PCO Course curriculum includes segments providing the critical information which the PCO will need to effect

decisions and implement productivity programs at the field activity level. It is expected that by the end of calendar year 1981, eighty percent of naval industrial activity COs will have been indoctrinated in the Navy's Productivity Enhancement Program. By 1982, and thereafter, all industrial activity commanding officers should have a working knowledge of the program, its accomplishments and objectives.

2. Distinguished Lecture Series. This initiative, started in November 1980, involves a host of distinguished lecturers from government, academia, industry and labor. Attendance is by nomination, involving a select group of senior Navy line managers. These face-to-face encounter sessions with the leaders in the world of productivity provide for a continuing infusion of new ideas for Navy's senior managers.

3. FYI. FYI is published quarterly by the Naval Material Command as a mechanism to keep Navy personnel up-to-date on the status of programs, new initiatives and matters of general interest in the field of productivity.

4. Seminars and Workshops. The Naval Material Command and its constituent Systems Commands regularly host seminars and workshops in the field and at headquarters to keep managers at all levels involved in the dissemination of information and the formulation of plans for future action. During FY 1980, more than a dozen such seminars and workshops were hosted.

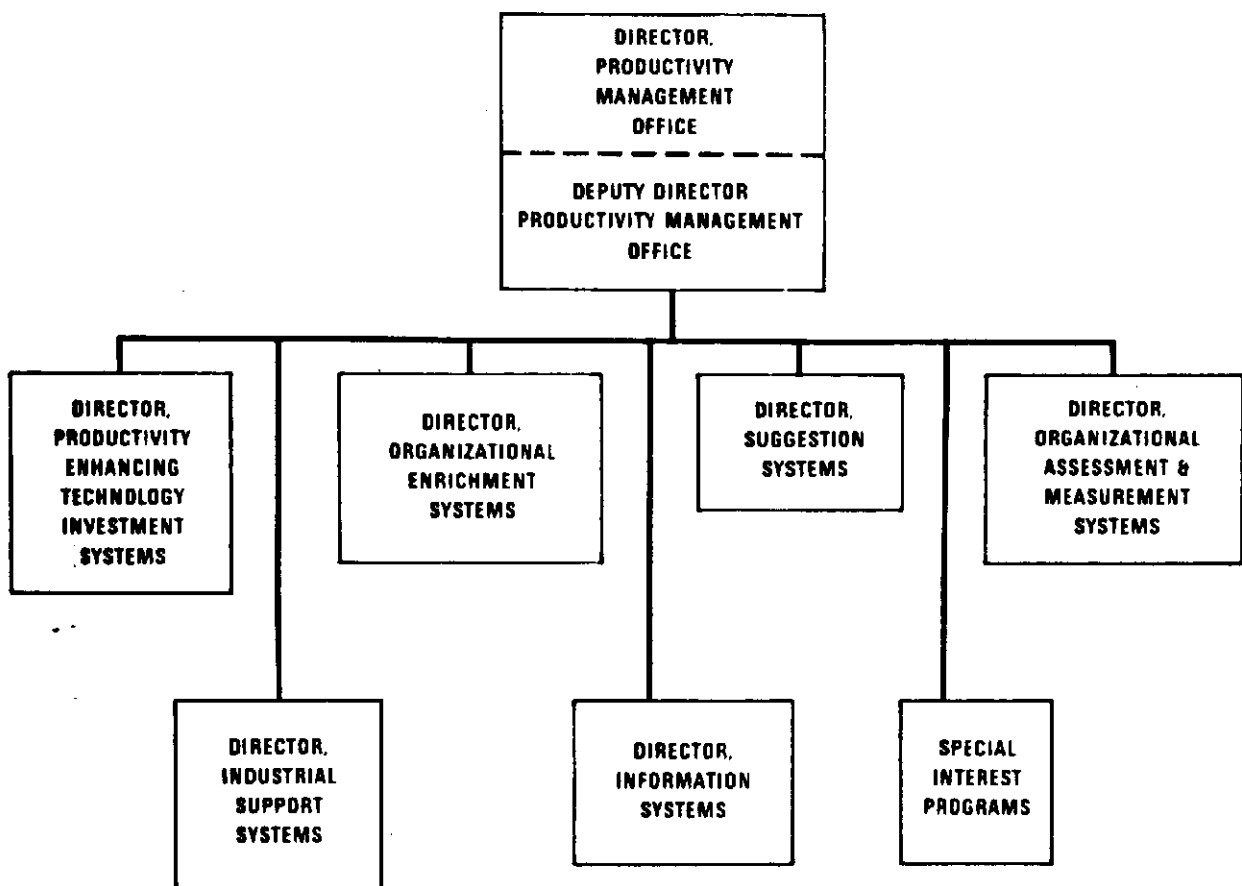
d. Disincentives to Productivity. In addition to the pursuit of programs to improve productivity by enhancing motivation, there exists a need to identify factors which may inhibit or discourage productivity. In January of 1980, the Naval Material Command sponsored a study to isolate impediments to productivity within the Navy's industrially funded logistics community (shipyards, naval air rework facilities, public works centers, supply centers and weapons stations). The purpose of the study was to identify factors which impede productivity and to recommend management actions to reduce their effect on productivity. The study was conducted by the Naval Personnel Research and Development Center (NPRDC) with technical assistance provided by the Office of Personnel Management.

The study was completed in October 1980. A detailed report of findings now serves to provide direction to a corporate team which is chaired by the Director of Productivity Management with membership from each major headquarters command representing the study participants.

Process Management. The ultimate objective of the Navy's Productivity Program is to improve military preparedness. Within the industrial segment of the Navy, military preparedness equates to the delivery of goods and services as required by fleet operators. To accomplish this objective requires a reasonable level of statistical control of major operations. Statistical methods are the only basis to forecast production capability, output, quality and cost. Measures of productivity must describe the extent to which management eliminates barriers to productivity (common causes of statistical variations), improves process efficiency (use of improved methods) and reduce product defectiveness.

The Navy is devoting considerable attention toward the development of statistically supportable measures of productivity. These measures involve headquarters and field activities and at this point focus on the individual, a group of individuals, and a major command (aggregate measures). Work toward the development of aggregate measures of productivity is in progress. These measures are expected to provide a useful tool to restructure systems of incentives and, for the first time, provide a realistic portrait of productivity in a military industrial work setting.

## **NAVAL MATERIAL COMMAND PRODUCTIVITY MANAGEMENT OFFICE**

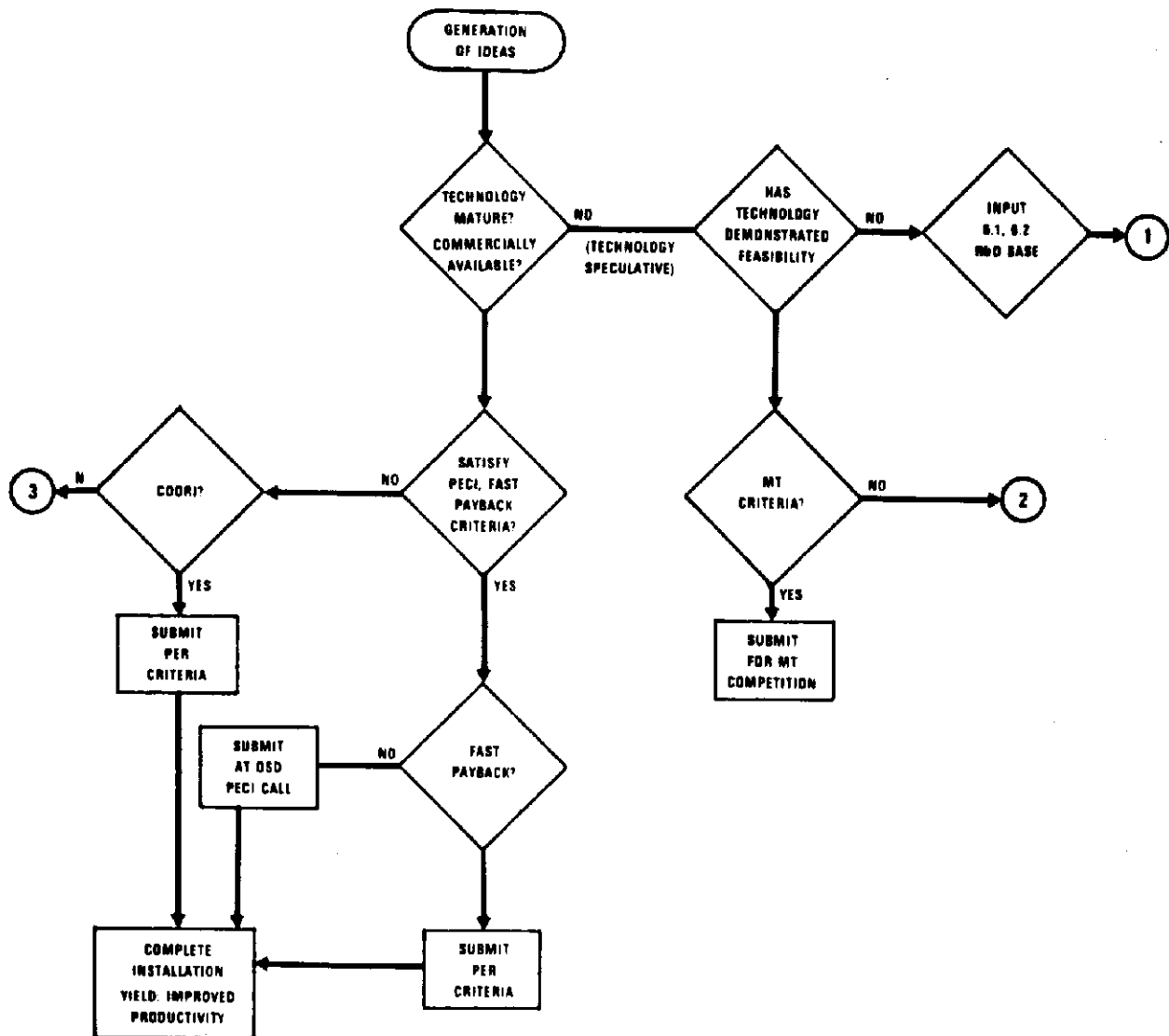


\*THE DIRECTOR OF PRODUCTIVITY MANAGEMENT SERVES COLLATERAL DUTY IN THE OFFICE OF THE ASSISTANT SECRETARY OF THE NAVY (MANPOWER, RESERVE AFFAIRS, AND LOGISTICS) AND THE NAVAL MATERIAL COMMAND.

FIG. 1



## CAPITAL INVESTMENT TECHNOLOGY DECISION MODEL



- 1 HOLD IN BACKLOG FOR FUTURE CONSIDERATION IN APPLIED SCIENCES OR ABANDON
- 2 EXPLORE ALTERNATIVE SUPPORT, NEED ASSESSMENT, ETC.
- 3 CONSIDER OTHER FUNDING MECHANISMS (ENERGY, OSHA, ETC.)

FIG. 2

## PRODUCTIVITY AND MOTIVATION - II

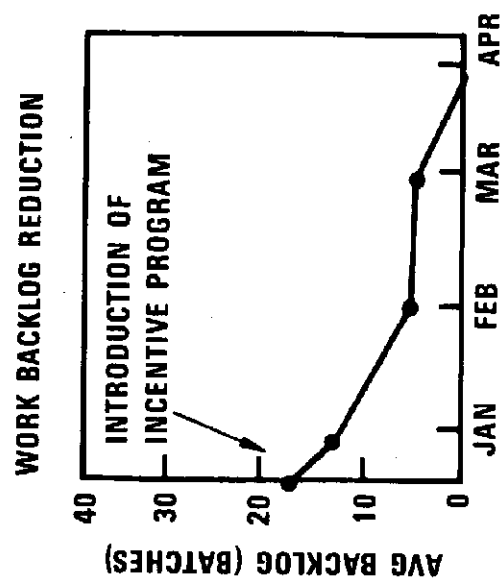


FIG. 3

## PRODUCTIVITY AND MOTIVATION - II

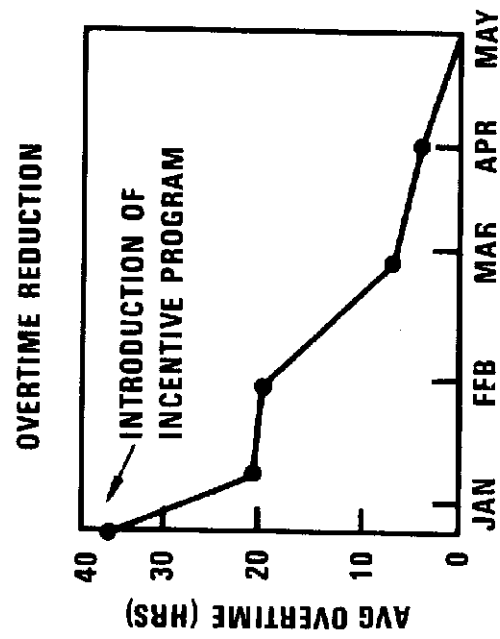


FIG. 4

QUALITY CIRCLES...  
DOING BUSINESS BETTER AT PHILADELPHIA NAVAL SHIPYARD

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ABSTRACT

An overview of quality circle philosophy and a status report on the quality circles at the Philadelphia Naval Shipyard are given. A management presentation is given covering problem identification and techniques and accomplishments and recommendations concerning the problem "loft time at tool room window". Other accomplishments and other problems under consideration are also discussed.

A videotape presentation entitled "A Time for People Building and Management Support" which discusses quality circles, and the role of management to support programs such as quality circles will be shown. A union president from Norfolk Naval Shipyard voices his support for the quality circle program, then the film focuses on a visit of the Chief of Naval Material, Admiral Whittle, to Norfolk Naval Shipyard to see quality circles in action.

A general overview of the Naval Sea Systems Command facilities involved in quality circles is presented, and in conclusion, keys to a successful quality circle program, and proper procedures for implementation are defined.

How can we fully utilize our greatest resource...people? There is a great wealth of untapped creative intelligence available in every company. The Quality Circle philosophy recognizes that the people actually doing the work are the true experts and that they can, and want to, contribute much more than their brawn. Quality Circles unlock the brainpower of people by allowing them to participate in making heretofore management decisions to improve their quality of worklife.

The structure is simple. Employees doing similar work, who have the same first-line supervisor and who volunteer to participate, are grouped together with their supervisor as the leader. They are trained in analytical problem solving techniques and meet weekly, for one hour on company time, to identify, analyze and solve problems in their work area. The voluntary aspect of participation is vitally important in that all true learning is voluntary and, furthermore, not everyone feels a need to contribute their ideas.

A facilitator is necessary to provide adequate training, assure strict adherence to the process, arrange for technical specialists to provide needed data and information, communicate with higher management about circle activities and conversely, provide feedback to the circles. The facilitator arranges for the management presentation once a

circle has solved a problem and assists them in any way necessary to achieve their objectives. In order to properly attend to these duties, the facilitator should: be present at every circle meeting, keep accurate records of what transpired, list persons in attendance, establish the next meeting's agenda, and note any requirements prior to that meeting. It is a full time job.

Philadelphia Naval Shipyard has seven (7) quality circles presently functioning representing four (4) major departments: Planning, Production, Public Works and Supply. In August, we trained additional leaders and will soon be expanding to thirteen (13) circles. There are two facilitators and a Program Coordinator. Further expansion will precipitate training another facilitator.

Data as of 4 September 1981 reflects a \$2.40 return for every \$1.00 invested in the program. The Quality Circle "Alpha Omega", a group of machinists, significantly reduced the amount of time required to obtain tools and effected a cost savings in excess of \$170,000. More important, however, are the benefits of improved quality and safety, fewer impediments to productivity, improved communication, and better morale resulting from employee involvement and support from management by cooperating with circle members' endeavors. Employees are now coming to management with solutions to problems, not just complaints.

To exemplify Navy top management support, a videotape entitled "A Time for People Building and Management Support", was produced by the Central Video Library at Norfolk Naval Shipyard. (Norfolk Naval Shipyard was the pioneer of Quality Circles in the Navy.) The tape focuses on the visit of the Chief of Naval Material Command, the Chief of Naval Sea Systems Command and other high ranking Navy officials to that shipyard to see Quality Circles in action. The message is clear from both the Navy and the local union. The Quality Circle Program is fully supported.

The Quality Circle approach to improving productivity has rapidly grown in the last two and one-half years in both the public and private sectors. According to a 21 February 1980 article in the Wall Street Journal, there were 65 companies in America with Quality Circles, "up from only 15 a year ago!" Today, the estimate is 500 companies. The Government Accounting Office stated that, their 6 November 1980 survey indicated 200 Quality Circles were active in the Federal Government. (That figure, according to OPM, probably doubled in the nine months following the GAO survey.) Naval Material Command, with cognizance over 210 installations, conservatively estimates that forty (40) of those installations have about 250 Quality Circles meeting regularly. Organizationally under Naval Material Command, Naval Sea Systems Command has about 100 Quality Circles in all of the eight naval shipyards across the country and several of the Naval Ordnance and Naval

Weapons stations. Circles are also active in the Army, Air Force and other Department of Defense facilities. Curtis Bay Coast Guard Station in Baltimore, Maryland, sent a representative to Philadelphia Naval Shipyard for facilitator training just last month.

Quality Circles are booming, but it is not a bandwagon to jump on. A lot of hard work is necessary to be successful. Here are ten (10) important keys to success:

1. Gain the support of management and labor.
2. Organize a Steering Committee of both top management and union officials to provide credibility and act as an advisory board.
3. Both participation and support must be voluntary.
4. Circles must have the freedom to choose problems they feel are most important.
5. Select capable facilitators.
6. There must be open communication with management about circle activities.
7. The facilitator must follow-up on implementation of approved solutions.
8. Strict adherence to the Quality Circle concept and procedures is imperative.
9. Quality not quantity should be the major consideration.
10. Proceed slowly!

In order to implement Quality Circles, one must establish a sequential plan of events. It is vitally important, however, because of the voluntary nature, that your plan is not locked into scheduled milestones. Obstacles which surface can be overcome with trust, caring and time. Although each Quality Circle program (truly the Quality Circle approach is a philosophy rather than a program) has its own characteristics and needs to be tailored to each company, there are several general steps to follow for proper implementation. Provided for your consideration is the following example:

1. SELL TOP MANAGEMENT - various consultants are available for help and usually advertise in technical magazines, e.g. "Quality Progress" published by the American Society of Quality Control.
2. SOLICIT UNION SUPPORT - emphasize benefits to the employee as well as the company, A cooperative effort of labor and management can work wonders.
3. PUBLICIZE QUALITY CIRCLES - the entire workforce should be aware of what they are, how they are structured and the intentions of the company to implement circles in the near future.
4. ESTABLISH A STEERING COMMITTEE - top and middle management, union officials and, after selection, the facilitator should be its members. (This forum is used at the Philadelphia Naval Shipyard to the extent of an advisory board to the Program Coordinator is responsible for the success of the Program.)



5. SELECT A FACILITATOR - a volunteer who is truly committed to the Quality Circle philosophy and concepts and is comfortable communicating with all echelons of management, the union and the workforce. The Steering Committee can help to identify potential facilitators.
6. TRAIN THE FACILITATOR - training is available through outside consultants, the American Productivity Center and the International Association of Quality Circles.
7. MAKE PRESENTATIONS TO MIDDLE MANAGEMENT - avoid efforts to force Quality Circles into areas where they are not wanted. Following the path of least resistance, continue presentations through the chain of command and to the worker. This will assure genuine support and interest, without which circles will fail.
8. START SMALL - recognizing that the concept, process, techniques and the facilitator are new and, most likely, it is a new style of management, do not bite off more than you can chew. Three to six circles can provide for a good pilot program.
9. TRAIN LEADERS AND MEMBERS - manuals are available from consulting firms and other resources previously mentioned. Assure that an adequate number of member manuals are on hand at the time of leader training to avoid loss of continuity and enthusiasm drain.
10. EXPAND GRADUALLY - resist pressure to add a large number of new circles. Expansion requires training

more facilitators. Although dependent upon individual abilities, a good rule of thumb to follow is seven to nine circles for each facilitator.

Remember that the primary emphasis is "people-building." Look for long term effects. ..not a quick fix to your company's quality and productivity problems. Quality Circles will result in change in both the employee attitudes toward their job and the style of management throughout the company. These changes must be nurtured slowly or they will be strongly resisted.

## ' SPADES' SYSTEM ON INTERACTIVE GRAPHICS

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### ABSTRACT

The unique requirements of shipbuilding do not afford easy application of graphics systems from other industries. During hardware demonstrations, graphic tubes appear like the solution to all problems with the ease of representing geometry on the screen. But is it really enough to just produce a beautiful picture, a ship part or a nest tape? Where in the ship does this part belong? What happens if a drawing revision affects the part? If the instructions that produced the original were not saved, the entire part would have to be redone, instead of just introducing the changes. Playing with the light pen does not make a productive system, and if not properly handled, the new tool may become a new toy, fascinating people and wasting their time, instead of contributing to the production.

The ' SPADES' System is designed to work either in batch or in an Interactive Graphic mode. This is made easy by the fact that all ' SPADES' Modules-- in addition to using the same input handling routine and postprocessor--make extensive use, also, of common general routines; and therefore, no incompatibility exists between the various modules.

One of the major considerations was to have total interchangeability between the graphic and batch mode of the system such that rework could be processed easily, whether the original work had been done through the 'CRT' or in batch. The requirement was also set that none of the ' SPADES' management and control features would be compromised because of graphics.

## INTRODUCTION

In 1975, the decision was made to develop an interactive graphics version of the 'SPADES' system. This development was completed in the fall of 1976, with all development efforts directed toward the IBM 2840/2250 hardware. While this version of the system is used extensively by the large shipyards, the equipment cost is prohibitive to most small and medium sized shipyards. This created a problem with the smaller yards, as well as with Cali and Associates, in attempting to cost justify the advantages of interactive graphics. To alleviate this problem, Cali and Associates made the decision to redirect its efforts toward the smaller computer and to utilize less expensive terminals for interactive graphics. This decision caused a complete re-evaluation of the interactive graphics version of the 'SPADES' system.

After a complete conversion of the 'SPADES' system to a Prime 400 computer in 1978, a major development project was started to design and code, in its entirety, a truly interactive graphics version of the 'SPADES' system.

As design efforts began, it became apparent that the most logical approach to the system development was to completely describe all common features required in any interactive graphics module, and to isolate all of these features into a generic subroutine library. This library of common subroutines was written with two major objectives in mind. The first objective was to establish and maintain compatibility with the existing 'SPADES' graphics modules, and secondly, remain hardware independent. While the development of this library has spanned two years, the time required to create an interactive version of any particular module has been greatly reduced. An example of this is the three weeks required to write the first version of the Nesting Emulator, as used in production at Cali and Associates. Since that time, the Part Generation and Validation Modules, as used at Avondale Shipyards in New Orleans, Louisiana and National Steel Shipbuilding in San Diego, California, have been converted to run on the in-house equipment.

## DECISION TO DEVELOP GRAPHICS

Cali and Associates, Inc., the developers and marketers of the 'SPADES' software, are able to offer a wide range of Numerical Control services to the shipbuilding and fabrication industries. The demand for these services has been increasing at an inordinate rate, which is inversely proportional to the manpower curve. It is a recognized fact, that with the passing of each year, it becomes increasingly difficult to replace experienced loftsmen, layout men, and shipfitters. The causes of this problem are various and outside the scope of this paper. The effects, however, are with us and we must live with them. The adoption of interactive graphics offers the best solution to this problem because:

Less experienced personnel can be used for certain tasks.

The average required level of skill can be lower and still produce a product of quality at less cost.

The computer industry has greatly enhanced the use of interactive graphics in the small and medium sized shipyards with its introduction of low to medium cost hardware, which is easily interfaced with the various interactive terminals. Considering the aforementioned, Cali and Associates easily decided to develop their own interactive graphic version of the 'SPADES' system.

### III HARDWARE SELECTION

The first consideration in any major design project, naturally, is to select hardware which closely supports all of the requirements of the desired system. There are two classic concepts in the architecture of interactive graphic terminals which one must consider. The first concept in CRT design is the storage display tube, which permits circuit simplification, makes the hardware easy to operate, inexpensive to maintain, and economical to purchase. This design concept has one restriction which is unsatisfactory in the approach to interactive graphics as applied by Cali and Associates. The storage tube does not allow for elements to be moved from place to place on the screen without erasing and redrawing the entire picture. The second concept in architecture eliminates this restriction and provides total dynamic interaction in the refreshed mode by regenerating each vector a certain number of times per second, giving the illusion of a fixed picture. By applying this type of hardware, the user has complete control of the data as presented to the screen. The picture may be moved, element by element, as required. Cali and Associates decided the latter concept to more closely meet all of their requirements.

### IV OBJECTIVES

With the original decision to proceed with the development of an interactive graphics version of the 'SPADES' system, a list of requirements and goals were made and all of those objectives were met. To compromise these standards in any new development efforts would not have been in the best interest of any of the 'SPADES' users. Thus, the new version of the graphics system was designed to maintain all of the original standards, as well as establish new goals.

The major consideration is to have total interchangeability between the graphics and the batch versions of the system, such that rework can be processed easily. Regardless of the efficiency in any system, if rework has to begin at step one, all of this efficiency is lost.

An idea conceived by this company in its new design efforts was, while not to eliminate certain functions, duplicate them in the background as the graphics system is in progress; While these efforts are transparent to the user at the time of performing the graphics, the assurance that if the task has to be reworked for any reason, the effort is reduced to the smallest possible extent. We are happy to announce that these objectives have been met.

## V DEVELOPMENT TASK

### A. Generic Subroutine Library

Cali and Associates believe that the key to effective interactive graphics system development lies in definition of the user/system interface. The system was designed with the following guidelines governing each phase of development.

- Use of the system must not require the application programmer to be intimately familiar with the system software.
- . Proper use of the system must require minimal training.
- . All recurring applications should be identified and designed separately allowing the user to perform these applications with a minimum amount of effort.
- Error handling routines should be designed with the user in mind, allowing, whenever possible, the decision to act on these errors to be made at the application level.

A complex network of subroutines which lie resident in the host computer were developed to perform major graphic operations as required by the application programmer. This generic subroutine library currently consists of some two hundred (200) subroutines and is constantly growing as the need arises. The organization of these subroutines allow the application programmer an easy means to control display, zooming or window capabilities, geometric computations, translation and rotation, manuscript generation, manuscript updating, and many others.

## Display Control

The display control subroutines are designed to act on all input of data to the graphics terminal from the host computer. Two sets of limits are computed internally to properly display these data to the screen. These limits are the virtual picture limits and the virtual picture window limits. The computation of limits would, in other applications, be the responsibility of the application programmer, but since this package is designed to support the 'SPADES' numerical control system, these data are predetermined. The user must, however, provide to the system the location on the screen where the picture is to be drawn. All scaling and transformation is then computed by the system. This set of subroutines also provides the user an easy tool to create menus at the application level. Substructured at the menu level is the option to collect data directly through the terminal. This group of subroutines was designed explicitly for hardware independence. To achieve this, the package was written at two levels.

Level one interfaces directly with the 'SPADES' database. All data used by the graphic CRT is buffered in the host computer in the proper format of the 'SPADES' Modules. This level of subroutines will require no modification in the conversion to a new hardware configuration.

Level two interfaces to the in-house graphics CRT. These subroutines are hardware-dependent and would have to be modified should the reason to convert to a different piece of hardware arise.

By applying this approach, Cali and Associates believes that conversion to different equipment will not become a major effort.

## Zooming or Window Capabilities

The windowing capabilities inherent in the 'SPADES' graphics software allows the programmer to ask for a portion of his picture to be displayed at full screen size. The user must supply two screen positions which represent the diagonal of a rectangle to be used as the new view port. Scaling is then computed for the display of all elements falling within the boundaries of this view port. All other elements are clipped out by the 'SPADES' system to reduce terminal storage requirements and data transmission time. The full size, or original picture, is placed in the invisible mode to be made visible again on the call to exit the window. This eliminates the laborious task of regenerating the picture each time a window is requested.

### Geometric Computations

A comprehensive geometry package was designed and implemented in version I of the 'SPADES' graphics system. This package was modified to support all geometric calculations required by the new release.

A synopsis of the geometry computations follow:

- .line
- . line/line
- . line/arc
- . arc
- . arc/arc
- . point generation
- . line/point
- . arc/point

All geometry requests are made by, and controlled with, the light pen. Each element previously displayed on the CRT screen is uniquely identified by its own correlation value, allowing the user to select any displayed element from the screen. This correlation value is then used to locate the proper element from the host resident data buffer. The computations are performed against these data elements, thus preserving the integrity of the computed output.

### Rotation and Translation

The refreshed CRT allows great flexibility in the way that pictures may be manipulated on the face of the screen. One of the major advantages of this type of hardware is its ability to reproduce a portion of the picture while leaving the rest of the picture undisturbed. By regenerating the picture in even time intervals at different locations on the screen, the system programmer can create the visual illusion of dragging a part across the screen or of rotating the part around a given point. The translation and rotation of drawings on the screen plays an integral part in the total design concept as used by Cali and Associates.

### Manuscript Generation and Updating

As much as we would like to think otherwise, experience has taught us that changes and revisions are an ever-present way of life during the ship design and construction process. In order to maintain the efficiency inherent in any graphics system, rework must be taken into consideration. Cali and Associates have designed inverse code capabilities into their graphics library. This unique function will generate all of the cards, in their proper format, to execute the 'Batch' version of the 'SPADES' Module.



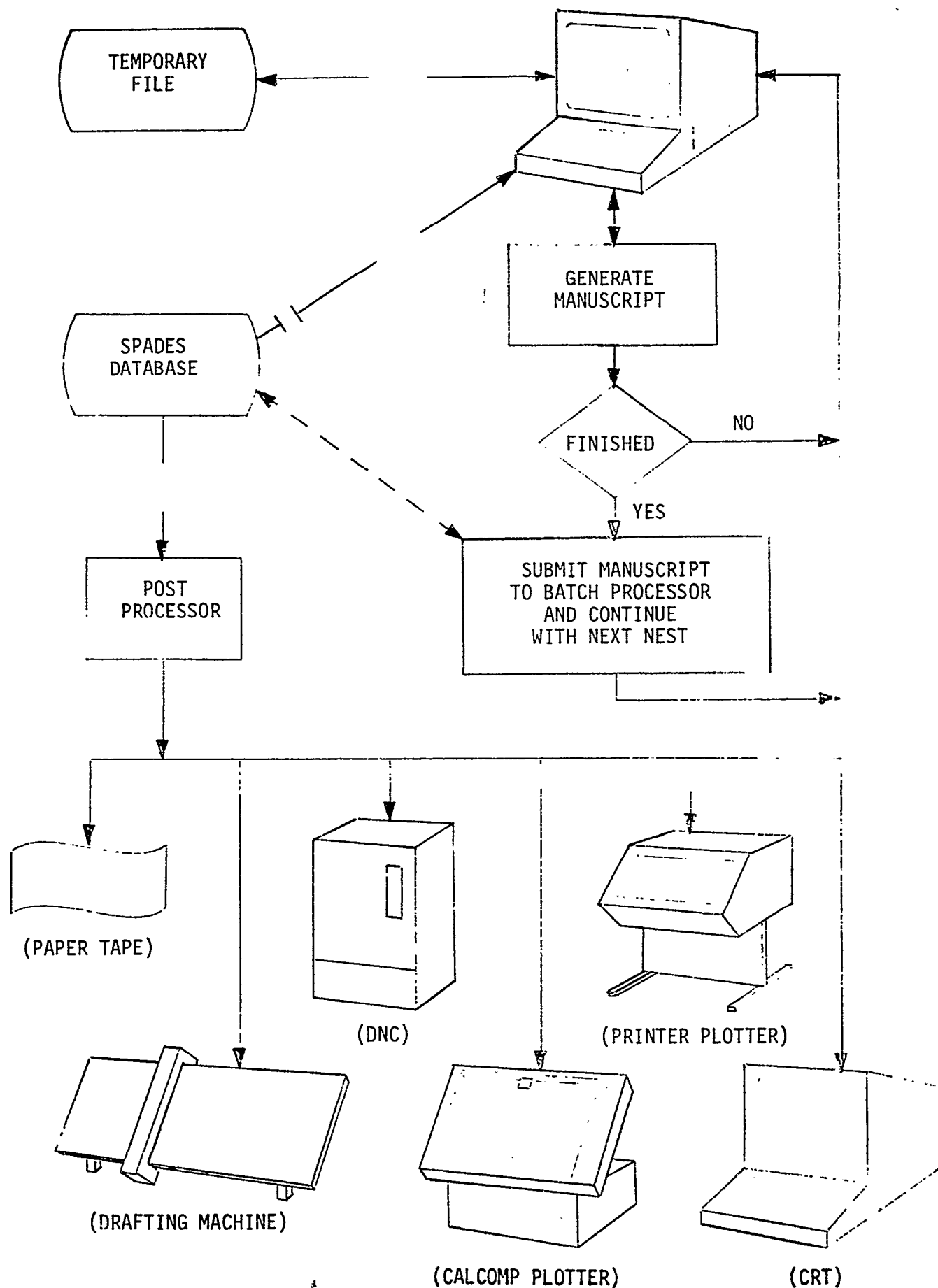
With no intervention from the user, the program is completely coded and stored in the 'SPADES' data base. Should rework be required in this area of the ship, the user has the choice of two simple procedures to follow.

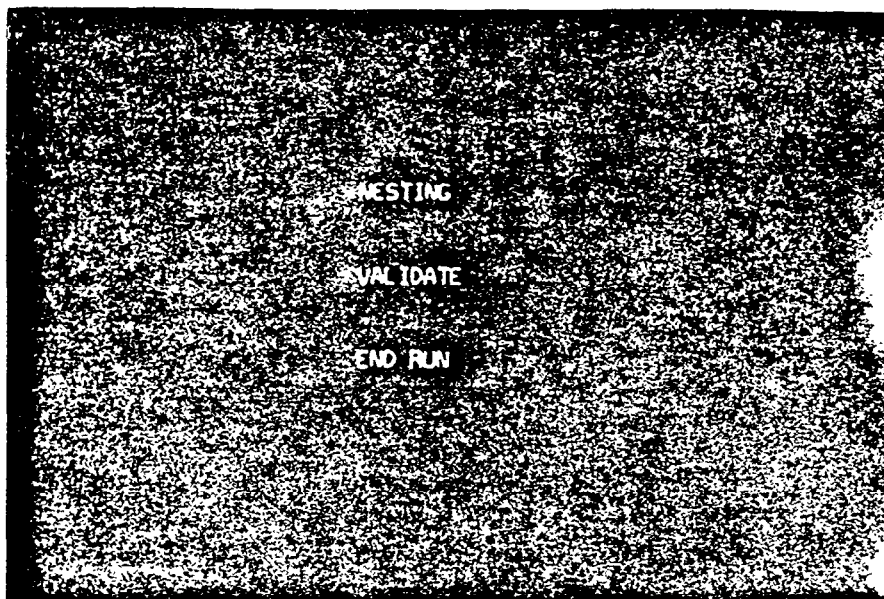
The first and most desirable procedure is, after the user recalls his manuscript from the data base, the graphics program will interpret each card, reconstruct the drawing without user intervention and return control to the user.

Secondly, the user may make minor updates to the manuscript through the 'Batch' version of the Nesting Module.

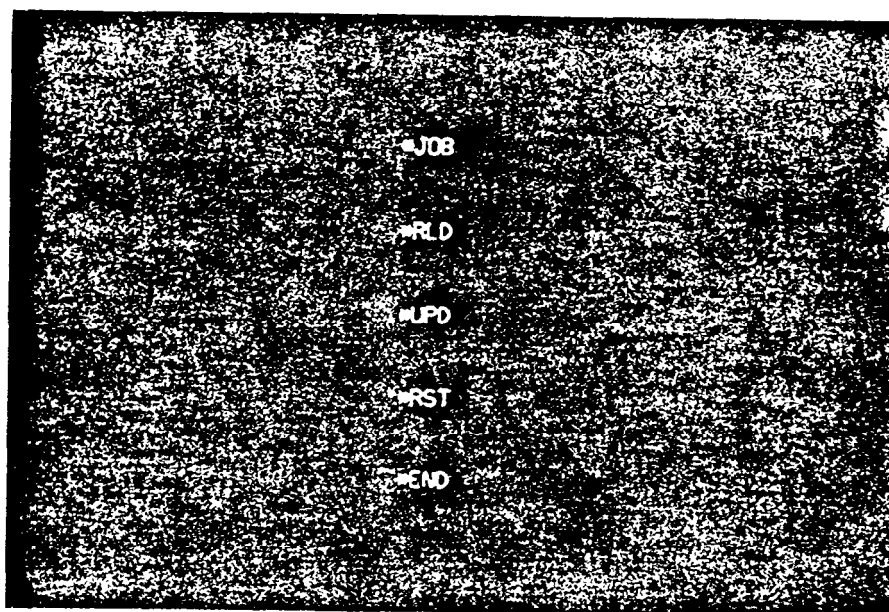
## B. Nesting Emulator

The interactive graphics version of the nesting module as used in production at Cali and Associates was designed and written to act as a stand-alone module in the 'SPADES' system. The functions of the graphics version of the nesting module are to provide to the user a visual representation of the location of parts on the plate, to modify, add and/or delete labels as required on these parts, and to control punch marking, hole selection and burning sequences. The following illustrations represent the nesting sequence as provided through the interactive graphics nesting module.

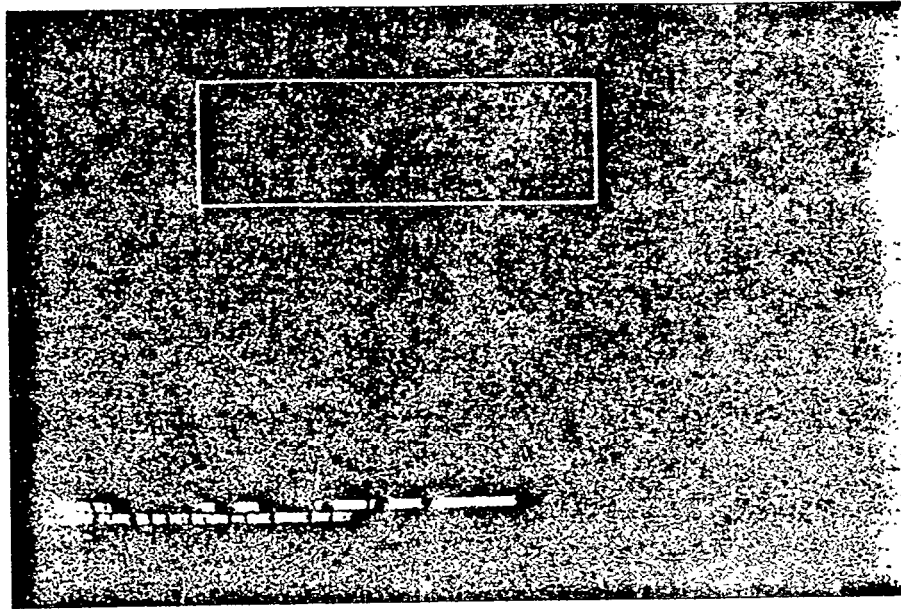




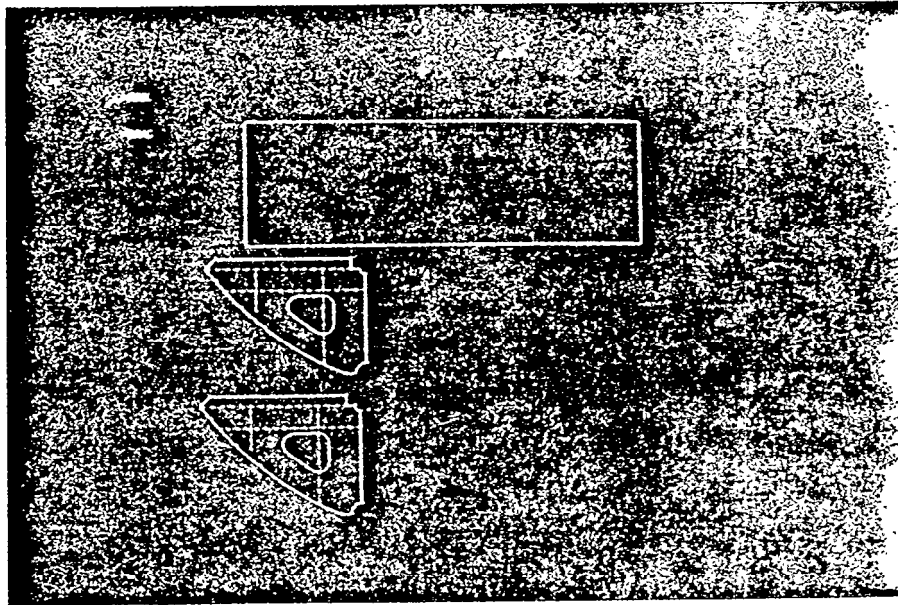
SELECTIONS AVAILABLE



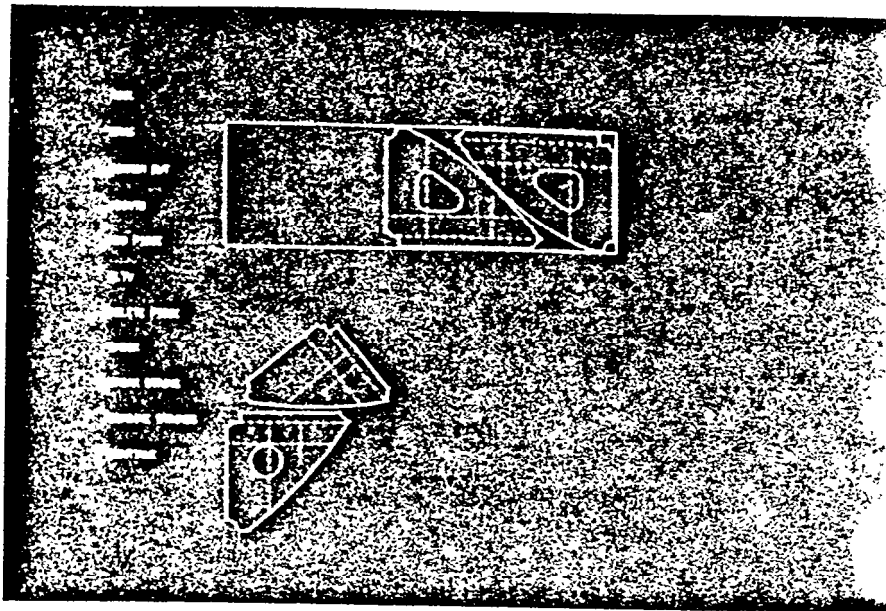
OPTIONS AVAILABLE IN NESTING MODULE



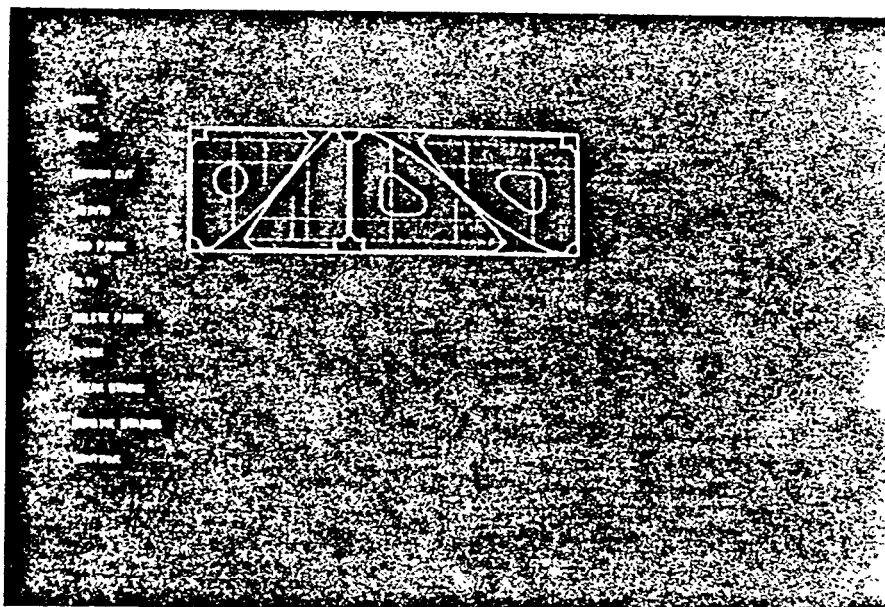
ENTER AND VERIFY PLATE SIZE



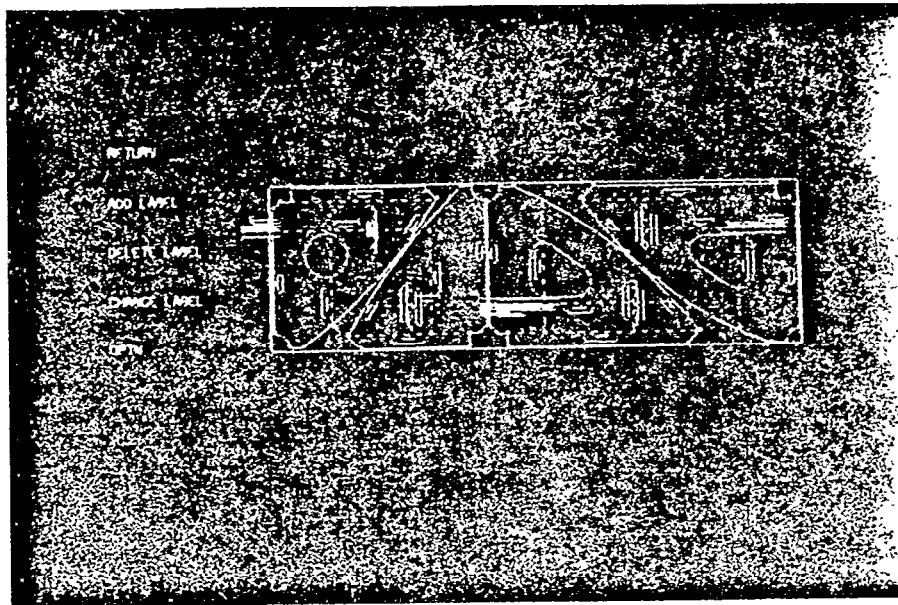
CALL PIECES FROM DATA BASES



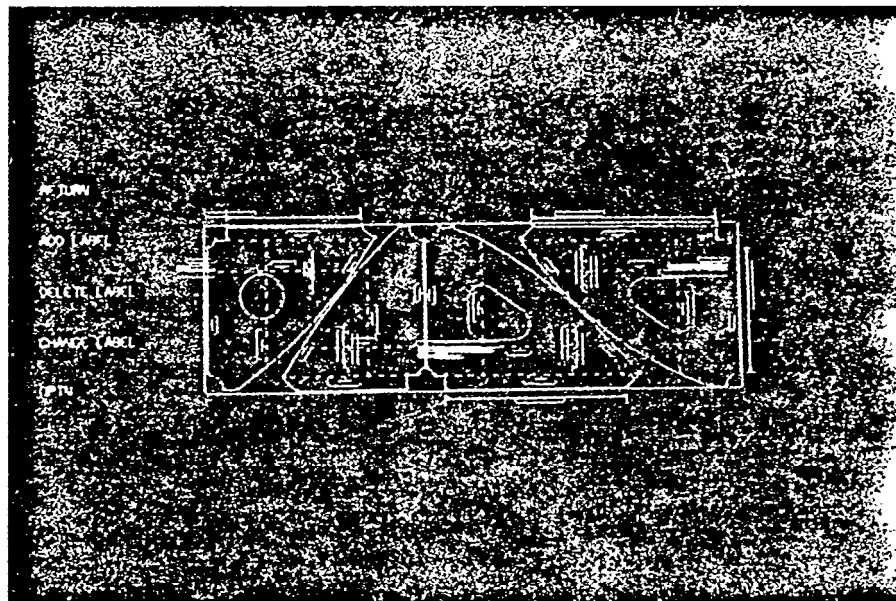
LOCATE PARTS ON PLATE  
CALL MORE PIECES FROM DATA BASE



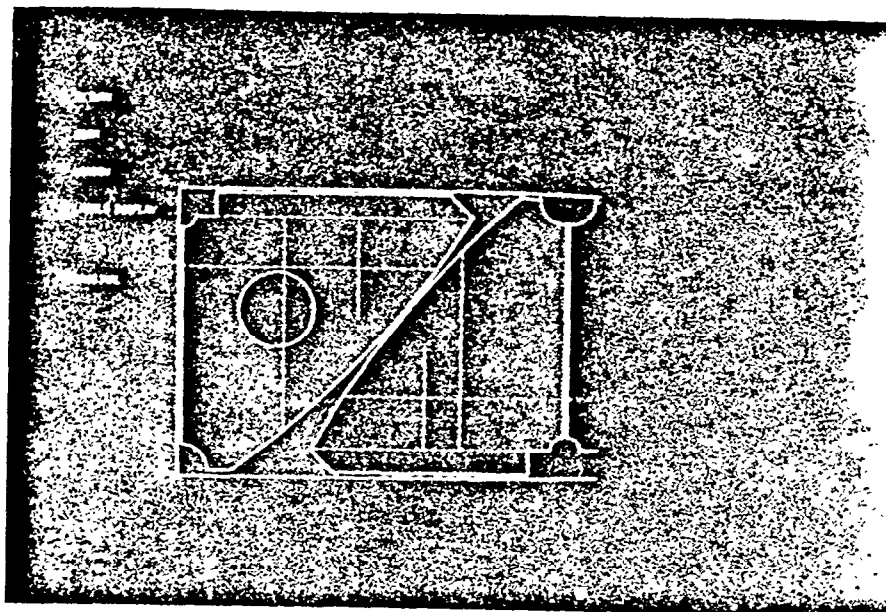
ALL PARTS LOCATED ON PLATE FOR NESTING



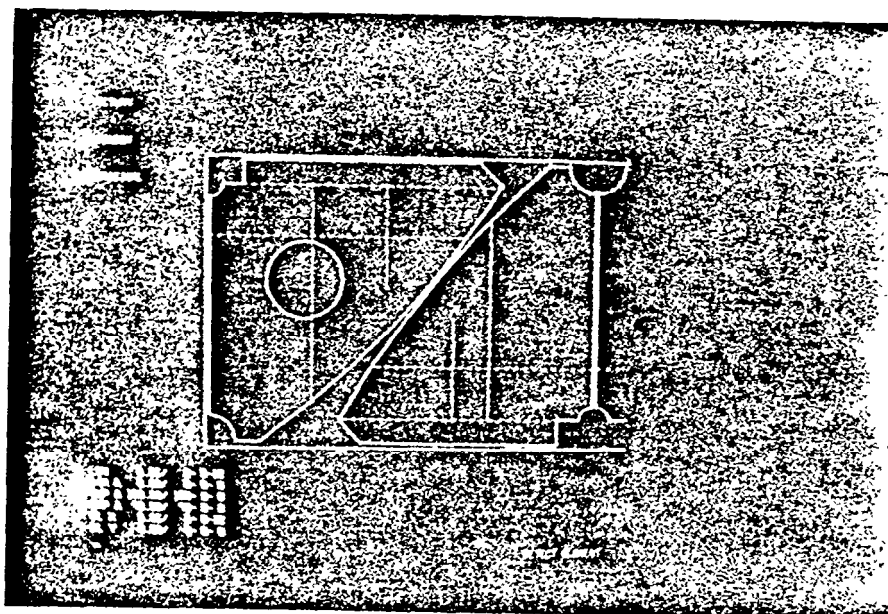
DISPLAY ALL LABELS



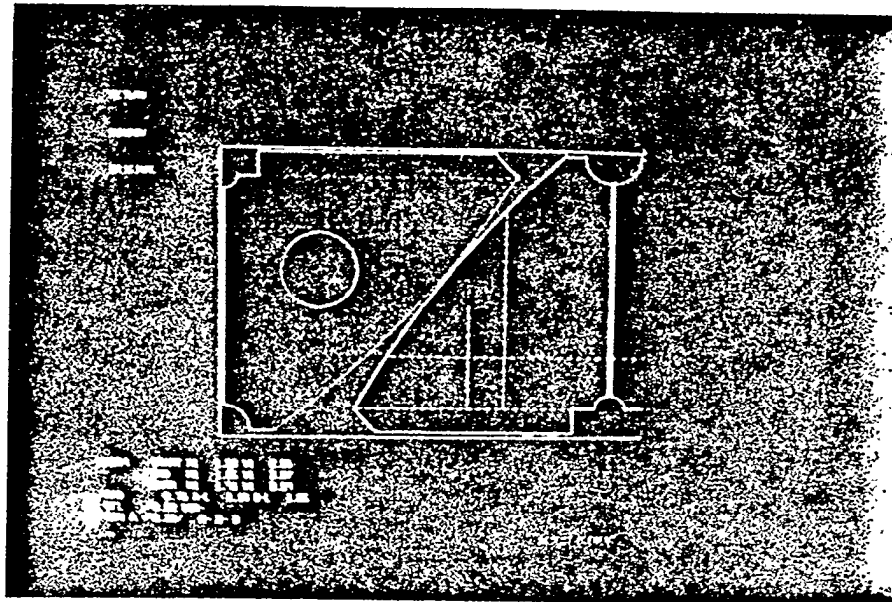
ADD CHECK DIMENSIONS



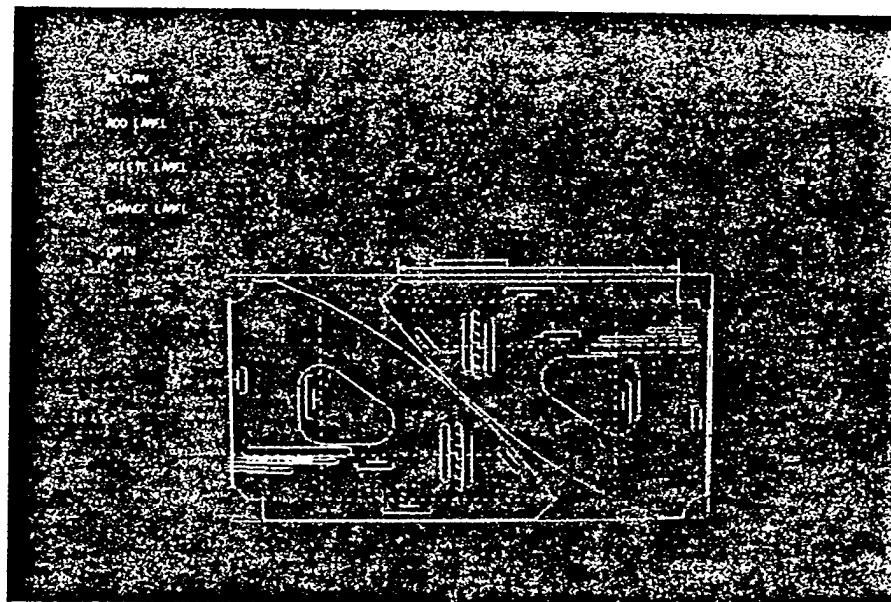
WINDOW PORTION OF PICTURE



CHECK GEOMETRY UNDER WINDOW

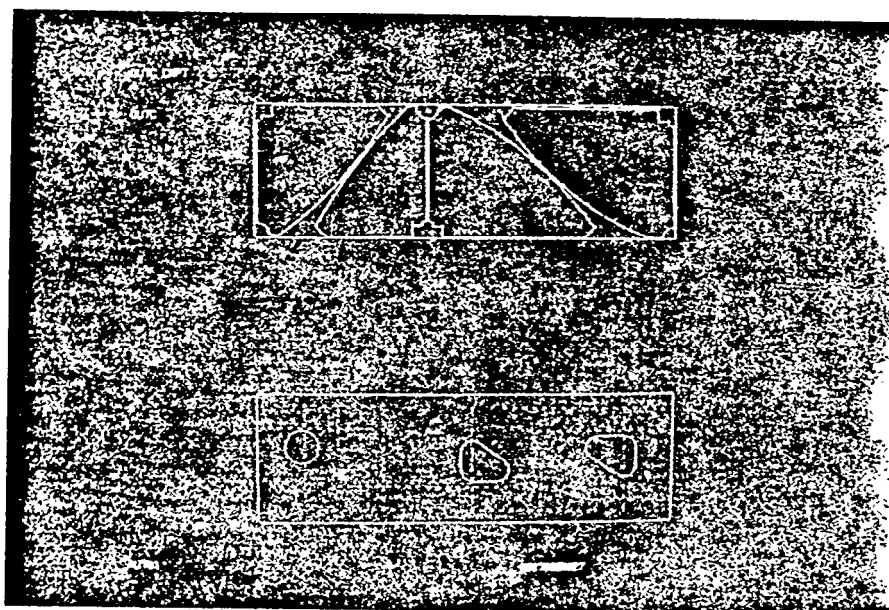
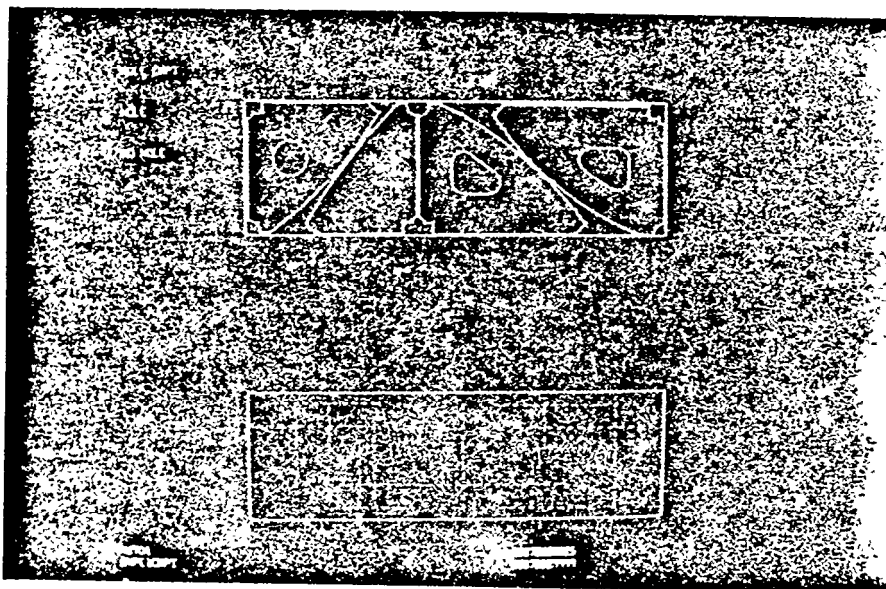
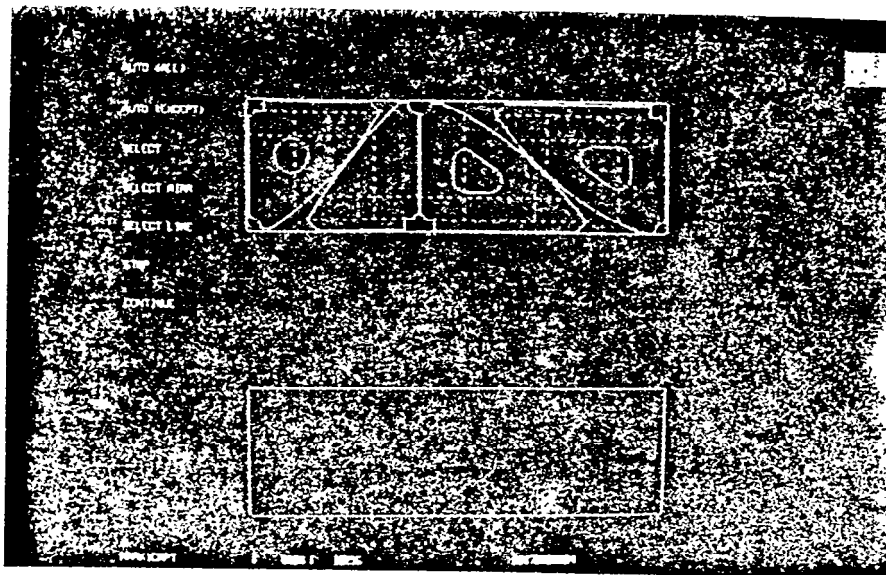


GEOMETRY WITH POINT ENHANCEMENT

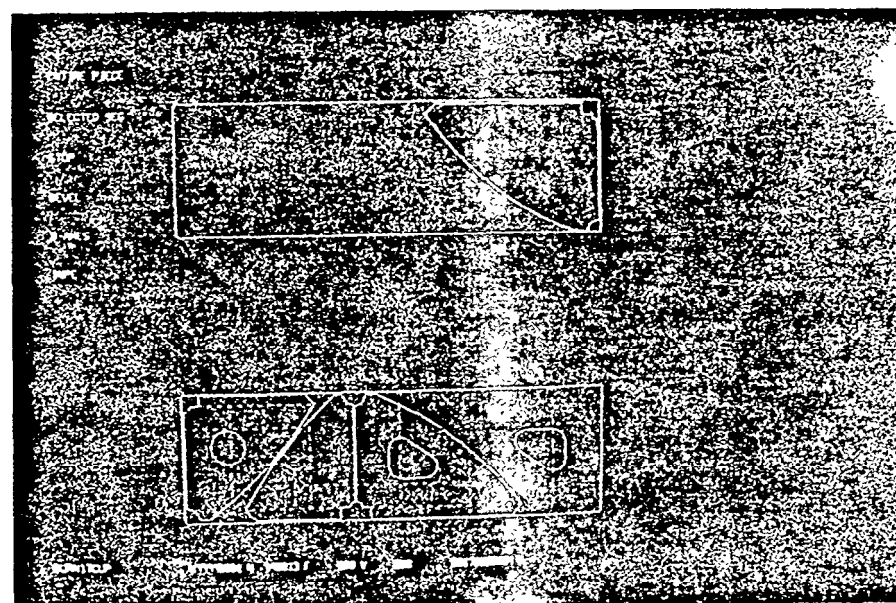
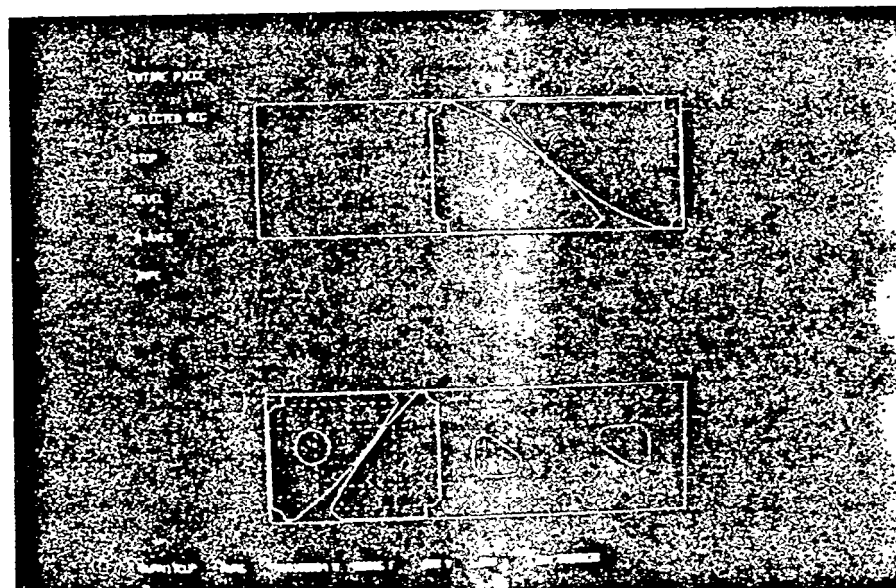
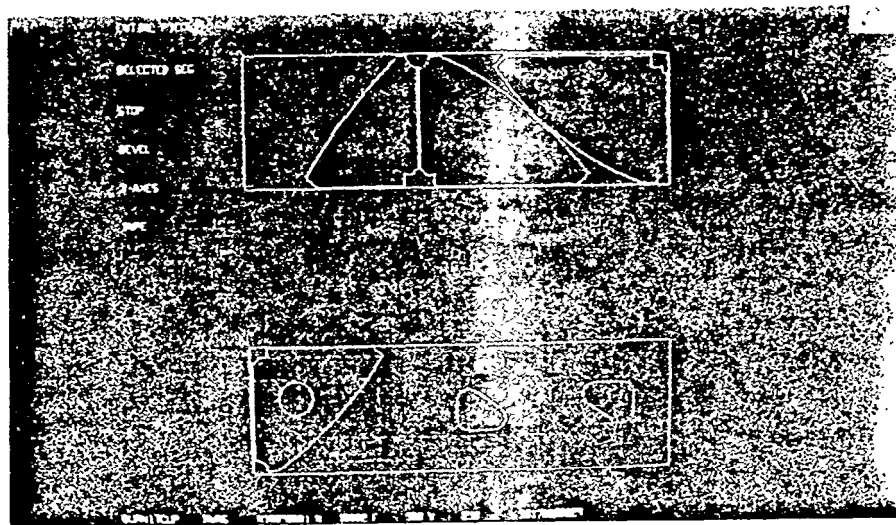


ADD, MODIFY & DELETE LABELS UNDER WINDOW

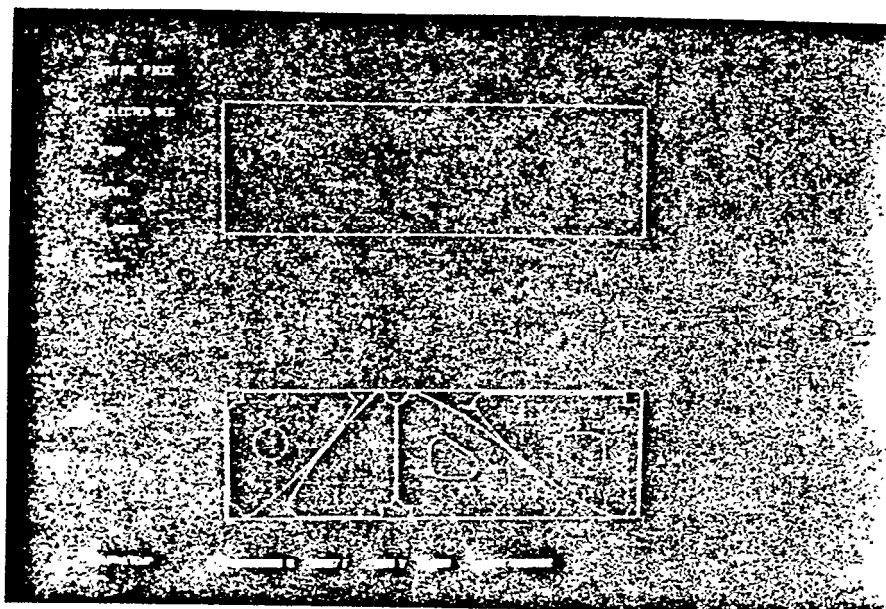




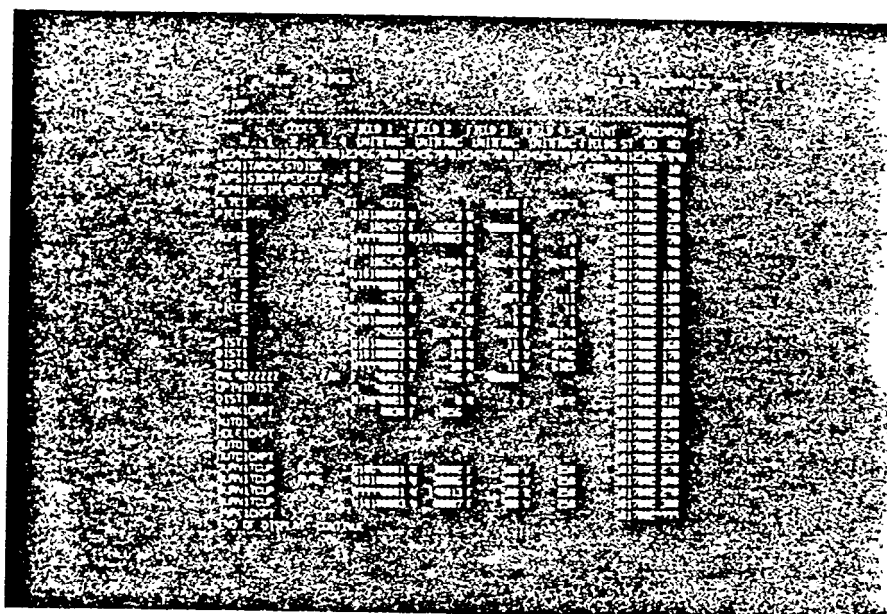
SELECT & TRANSFER CENTERPUNCHING  
& HOLES TO THE BURN PLATE



SELECT AND TRANSFER  
OUTER CONTOUR SEGMENTS TO BURN PLATE

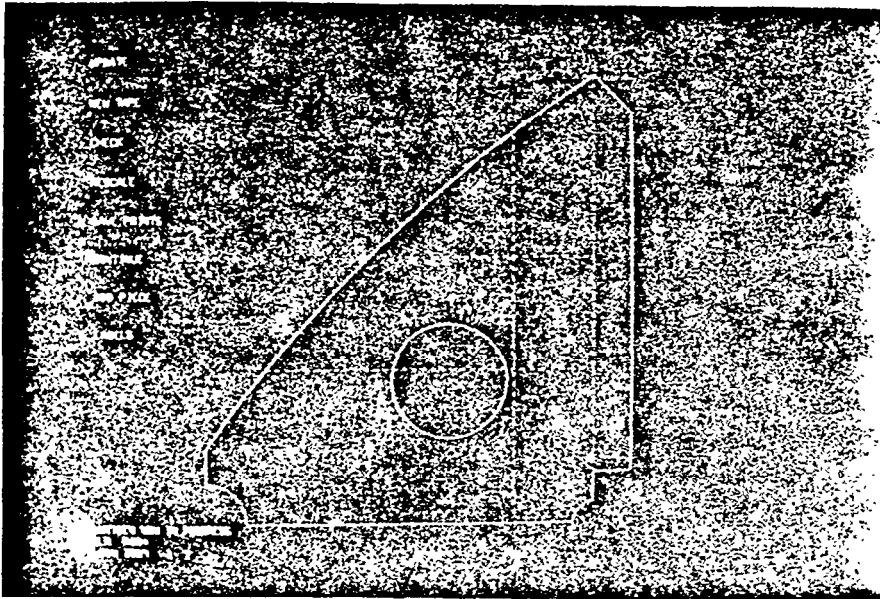


BURN SEQUENCE COMPLETED

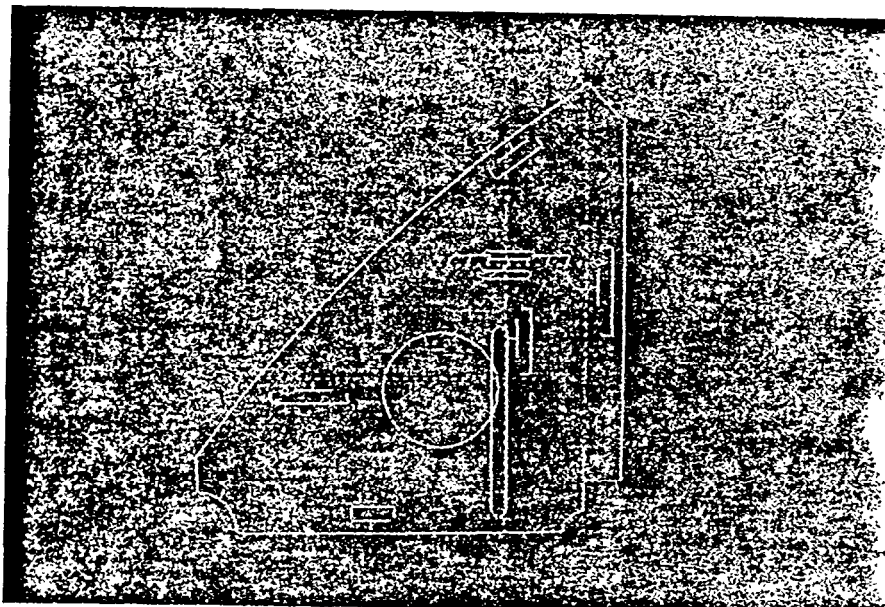


MANUSCRIPT GENERATED

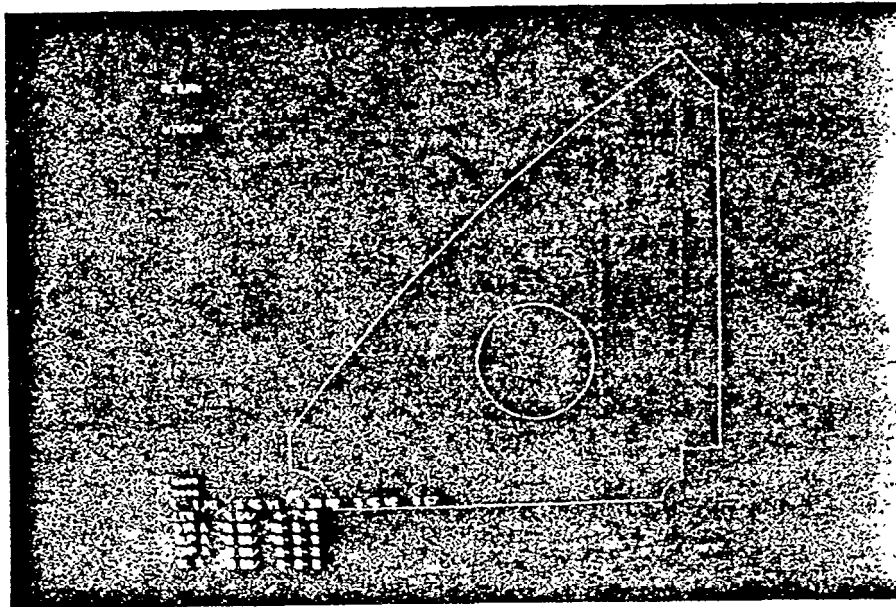




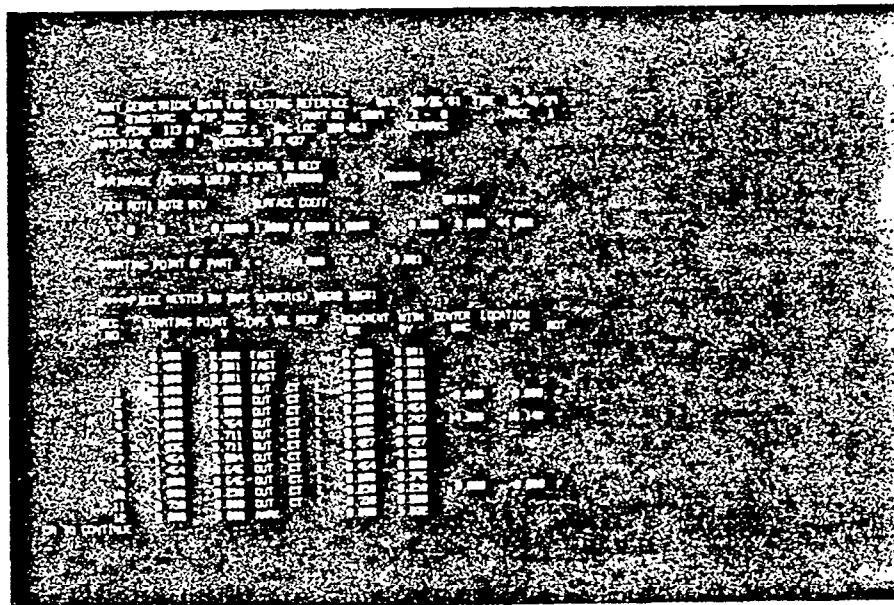
PART IS GENERATED THROUGH INTERACTIVE PARTGEN



DISPLAY AND CHECK LABELS



CHECK GEOMETRY UNDER PARTGEN



DISPLAY NESTING INFORMATION

## VI

HARDWARE CONFIGURATION

## A. MAINFRAME

PRIME 750 (Virtual Memory)  
 ACTUAL CORE - 2.0 Megabytes

## B. DISK STORAGE

DRIVES (300 Megabytes) Qty. 3  
 CONTROLLERS Qty. 2

## C. GRAPHIC 'CRT'

IMLAC Model 3205 Qty. 2

## D. PERIPHERAL EQUIPMENT

PRINTERS Qty. 2  
 PRINTER PLOTTER Qty. 1  
 CARD READER  
 DRAFTING MACHINE Qty. 1  
 CALCOMP PLOTTER Qty. 1  
 PAPER TAPE READER/PUNCH Qty. 1  
 ALPHANUMERIC TERMINALS Qty. 9  
 MAGNETIC TAPE DRIVE Qty. 1

## VII

CONCLUSION

Interactive graphics has become a very integral part of the shipbuilding industry. If used effectively and under proper management control, one graphic CRT with an efficient operator will produce upward to twenty completed nest tapes in one eight hour shift. It has been our experience at Cali and Associates that the complexity of the nest tape is irrelevant, and that the time required to complete a nest tape is directly proportional to the number of parts to be nested on the plate. The time to nest one part is approximately one minute, thus a nest tape consisting of sixty small brackets can be completed in one hour.

The reduction of man-hours using this approach allows for shorter construction periods with the same manning. Therefore, an increased output with the same facilities becomes possible with the consequent increase in total profit.

## MOST COMPUTER SYSTEMS: SHIPYARD APPLICATIONS

Louis Kuh  
H. B. Maynard and Company Inc  
Stamford, Connecticut

### ABSTRACT

An overview of the Most Computer System is presented, as it may best be applied in the shipyard, including the structure of time data for shipyard use. The simplicity and ease of preparing methods improvements with the computer aided materials are outlined, and finally, examples from shipyard applications are reviewed.



One of the basic needs in the shipbuilding industry is to know the true work content for each ship --- preferably in advance. Because of the "one of a kind" nature of shipbuilding, time study was considered to be useless as a general tool for defining work content in advance of construction. Predetermined time data - as it became available - provided the opportunity to define work content in advance of manufacture -- but the number of analyst hours required to define each hour of work was so high, that it was still considered impractical or uneconomical to use the systems. Nevertheless, the basic need for measure of true work content - as opposed to historical data - remained.

The use of predetermined time data to build standard data through tables and formulas was a further step towards reducing analyst time, and the fact that many basic operations were repetitive (such as the welding of panels) helped to reduce again the analytical time -- but it was considered to be too high.

The development of the Maynard operation sequence technique (MOST) brought us a work measurement technique that was specifically designed to accomodate long-cycle, non-repetitive types of work. When MOST was combined with the work management manual approach to recording and reporting data, it began to be feasible to measure the work content of the shipbuilding process. However, there were still two tasks that involved a considerable amount of manual effort: searching the files for existing reusable data, and totalling the "bits" of time into the large number of hours required for segments of a ship.

MOST Computer Systems has finally brought us to the stage of development that reduces the manual efforts of recall and summation -- plus! we believe that today we have a well defined work measurement system that is practical and economical for shipbuilding purposes.

SNAME Panel SP-8 on Industrial Engineering has provided the impetus and support necessary to implement MOST Computer Systems. As a result, we are getting the hands on experience needed to prove the value of MOST Computer Systems in the shipyard.

Incidentally, some of you who have had exposure to the Japanese shipbuilding techniques may feel that the industrial engineering program is extraneous -- since the successful Japanese Yards do not have an I.E. function. At this POI presentation, I will point out the fallacies in that evaluation.

#### MOST COMPUTER SYSTEMS - AN OVERVIEW

Last year at the IREAPS Conference, Maynard gave a detailed review of MOST and we will not attempt to go over all that ground today. In a quick review, MOST uses a family of six descriptive sequences to define manual operations, the use of tools, and the use of cranes and trucks for material handling. By using specific key words and a well defined sentence structure, a computer program has been prepared that permits an analyst to "write" the method as it is performed in a defined work area. The computer applies the proper sequence and the time values to the written method steps.

Before describing the basic procedure, let's look at the total program package that makes MOST Computer Systems.

There are five basic system programs and six supplementary modules programs that may be combined to provide the most usable system for a given situation. The programs are:

A. Basic Programs

1. MOST Analysis - The preparation of work area layouts and the methods description.
2. Suboperations Data Base - A file of completed method descriptions in suboperation and/or combined suboperation form.
3. Time Standard - The preparation of actual labor standards.
4. Standard Data Base - Same function as suboperations data base, except that complete standards are filed.
5. Mass Update - A program that permits overall modification of the time standards for the change of a common factor.

B. Supplementary Modules

1. Machining Data - The preparation of machining process times.
2. Welding Data - The preparation of welding process times.
3. Line Balancing - For complex assembly line operations.
4. Multi-man Machine Analyses - For making the best use of labor resources.
5. Word Processing - A program used for text and form preparation. A version of the program is specifically designed to prepare work management manuals.

6. Labor Reporting - for keeping track of labor utilization.

### THE MOST PROGRAM

The MOST program itself is, of course, the basic tool for time standard preparation. The program consists of two specific parts.

- A. The work area layout, and
- B. The method description.

The work area layout is a simple block diagram of the work area involved. Within the work area, we define workplaces (each location where work is performed such as a work bench, a machine, a storage rack, a space on the platen, etc.) and the things we find at the work places - such as the operator, pallets, tools, the objects we will be working with, and the equipment. Finally, we define the physical relationships or distances between each workplace. Figure 1 is an example of a work area in a fabrication shop where we will be bending brackets.

With the work area coded and defined, we are ready to write the method for a job in that area. Each method or suboperation is first coded and titled in accordance with a set of rules that has been established to simplify recall and future use of the suboperation.

Figure 2 is an example of a method for bending brackets in the work area illustrated in Figure 1. The program incorporates a tracking system that simplifies the way we describe a method step, and the operator, the objects and the tools are automatically traced from one workplace to another - or from a workplace to an operator or vice versa.

FABRICATION-SHOP-JOGGLER

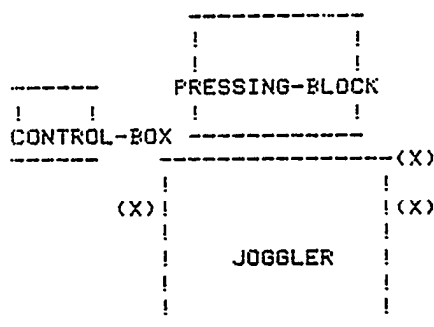
404

Figure 2

The Title is:

BEND FLANGE ON BRACKET AT JOGGLER  
PER EACH

0FG: 1 IO-SEP-B1

Operator ? CRANE-OPERATOR

Begins at Workplace ? JOGGLER

Method Step 1 ? CRANE-OPERATOR TRANSPORT BRACKET FROM IN-PALLET USING JIB-CRANE WITH TWIN-HOOK FREEING+LOOSE RAISING 5 FT. TO JOGGLER LOWERING 1 FT. AND ALIGN+ ACCURATE AND RETURN JIB-CRANE TO IN-PALLET

A16 T10 K24 F3 V32 L16 V6 F16 T16 A0 1.00 1390. '

Method Step 2 ? MECHANIC PICKUP MATERIAL-CARD

A3 BO GI A1 BO PO A0 1.00 50.

Method Step 3 ? MECHANIC READ 10 WORDS

A0 BO GO A0 BO PO T6 A0 BO PO A0 1.00 60.

Method Step 4 ? MECHANIC HOLD+MOVE MATERIAL-CARD TO CONTROL-BOX

A0 BO GO A1 BO P1 A0 1.00 20.

Method Step 5 ? MECHANIC PUSH BUTTONS AT CONTROL-BOX PTIME .5 S

A1 BO GI M1 XI IO A0 1.00 . . 40.

Method Step 6 ? MECHANIC SLIDE LEVER AT CONTROL-BOX PTIME 2.5 S ( LIFTING PRESS  
ING BLOCK )

A1 BO GI M3 X6 IO A0 1.00 110.

Method Step 7 ? HELPER PUSH BRACKET AT DIE AND ADJUST

A1 BO GI M1 XO 16 A0 1.00 90.

Method Step 8 ? MECHANIC SLIDE LEVER AT CONTROL-BOX PTIME 4.5 S ( FLANGING BRAC  
KET ) F 3

A1 BO GI M3 X10 IO A0 3.00 450,

Method Step 9 ? MECHANIC SLIDE LEVER AT CONTROL-BOX PTIME 2.5 S ( LIFTING PRESS  
ING BLOCK ) F 3

A1 BO GI M3 X6 IO A0 3.00 330.

Method Step 10 ? HELPER MEASURE FLANGE AT JOGGLER USING PROFILE-GAUGE AND ASIDE  
F 3

A1 BO GI A1 BO Pi M1 O A1 BO P1 A0 3.00 480.

Method Step 11 ? MARK BRACKET AT JOGGLER 13 DIGITS USING PAINT-STICK AND ASIDE

A1 BO GI A1 BO Pi R42 A1 BO F1 A0 1.00 480

Method Step 12 ? HELPER GET+PLACE BRACKET FROM JOGGLER TO FIN-BIN AND HELPER RET  
URN JOGGLER

- A1 BO G3 A3 B6 P3 A3 1.00 190.

Method Step 13 ? MECHANIC MARK JOB-CARD 7 DIGITS USING PENCIL-1 AT JOGGLER AND A  
SIDE ( SIGNATURE / DATE )

A3 BO GI A1 BO P1 R24 A1 BO P1 A0 1-00 320 .

Method Step 14 ? EX

Total TMU 4010.

If it is desirable to review the feasibility of a work area arrangement, you have the flexibility of editing an existing work area by changing distances, or workplace locations, or by adding tools, etc. You may then use the same method steps and get the new or revised time frame without having to rewrite the method, or you may edit the method description for the same effect. You have a simple tool for testing and evaluating methods changes without the manual effort of rewriting and preparing hard copy.

If the work area has been properly defined, you may associate almost any number of suboperations with a given work area.

The end result of the MOST program, then, is a number of work area layouts, with the associated methods descriptions or suboperations. Naturally, it is most desirable to define a suboperation as a unit of work that is repetitive in nature so that you may take the maximum advantage of the filing system described next.

### THE DATA BASE

Once the analyst - or user - has created a work area and a suboperation, the next step is to file the completed work in a permanent file where it can be readily accessed. That file is the data base. A suboperation like "place tube in bender" will be the same for many sizes of tubing, and for almost any subsequent bending operation. When we have the suboperation in the data base, we want to be able to recall it at any time we may need it.

By using a well defined title procedure for each suboperation, with a restricted and defined word list for title components, we are able to create a search routine that will enable us to recall any filed suboperation.

There are ten basic components to the title structure -- as follows:

1. ACTIVITY - A verb that describes the overall action being carried out, such as: BEND, BURN, or WELD.
2. OBJECT/ASSEMBLY/COMPONENT - A noun that describes the item receiving the action - such as: Bend TUBE, burn LIGHTENER HOLE, or weld STIFFENER.
3. "IN", "ON" "FOR" - You select the appropriate preposition.
4. PRODUCT/EQUIPMENT/ASSEMBLY - The item that the object is a part of, such as: bend tube for BOILER, burn lightener hole in WEB, or weld stiffener on DECK PANEL.
5. "WITH"
6. TOOL - The actual tool being used to accomplish the activity: bend tube for boiler with BENDER, burn lightener hole in web with TRACER BURNER, or weld stiffener on deck panel with MIG.
7. "AT" , "TO" - You select the appropriate word.
  - a. SIZE/CAPACITY/TYPE - A modifier for the next segment:  
Bend tube for boiler with bender at #875...  
Burn lightener hole in web with tracer burner at OPTICAL...  
Weld stiffener on deck panel with mig at #1...



9. ORIGIN - Specifies the work area or machine where the work is done:

bend tube for boiler with bender at 3875 GREENLEE...

burn lightener hole in web with tracer burner at optical BURNER...

weld stiffener on deck panel with mig at #1 WELD STATION...

10. MACHINE # OR WORK PLACE # - Specification of the exact machine or location involved:

bend tube for boiler with bender at #875 greenlee SHOP70

burn lightener hole in web with tracer burner at optical burner HARDINGE.

weld stiffener on deck panel with mig at #1 weld station PLATEN 2.

An individual designated as the data coordinator is assigned the task of filing each suboperation in the data base. He does not review the analyst's work, but does review the suggested title for completeness and accuracy. He files the suboperation in the data base after making sure that the title is correct and complete, and that the suboperation is not a duplication of something already in the data base. The computer will automatically assign a sequential locator number for use in future recall actions.

Once filed in the data base, the suboperation is available to all users. A user may search the data base by part or all of the title, and will be able to review some number of suboperation from which he may then select the one he can use, or can modify for use. He will copy the selected suboperation on his own file (electronically) and there he may edit it or modify it as required.

Combined suboperations may be created and filed in the data base by making combinations of suboperations that are involved in the manufacture of some end product.

We now have a data base that is a source of material for the time standard program, or for the development of additional suboperations.

### TIME STANDARD

A time standard is normally made up of a number of suboperations or combined suboperations, which may have different frequencies of occurrence, each of which is then modified by allowances for personal time, unavoidable delays, and human fatigue (usually referred to as P, F, & D) as well as an efficiency factor for a process time.

The time standard program is initiated with a header sheet that has a number of filing categories - similar to and for the same basic purpose as the titles in the data base program - and any other pertinent identifying or reference information. We then enter all the appropriate suboperation and/or combined suboperation locator numbers involved in the product, together with the proper frequency of occurrence for each one. The program will then prepare:

1. A METHOD INSTRUCTION - A step by step description of the work by suboperation title.
2. A TIME CALCULATION - A list of the steps in the standard, the frequency of occurrence assigned, the step time and the total time.

3. A RATE SHEET - A list of external manual times, internal times, and process times, showing the allowance percent, the allowance time, the standard time for each, the total standard time, the pieces per cycle, and the standard hours per piece.

The ability to produce those output documents makes the time standard program invaluable. We no longer need to have a large number of clerks turning out paper - nor do we need to maintain large file drawers full of records and documents. We can call up any of the documents we need in seconds -- and produce whatever hard copy we need at that time.

Another feature is the editing capability, which permits us to modify any individual standard as we make methods improvements or other changes. Engineering changes may be readily incorporated.

#### MASS UPDATE

The mass update program is another major convenience. Any time we find it necessary to change an element or suboperation that is common to many standards, or to change some assigned allowance, it would be laborious to make those changes either manually or one standard at a time. The mass update program allows us to identify the element to be changed, identify all the affected standards, and to make the change in all the standards simultaneously.

## WORD PROCESSING

The word processing program has the added advantage of a special version specifically designed to produce the work management manual. It will not only produce the needed text material, but can literally pull any needed material from other MOST Computer Systems files for direct inclusion in the manual, without the need of retyping the data.

As with any word processing program, it has the basic advantage of permitting rapid editing and constant updating to provide real time MOST Computer Systems documentation.

## THE MACHINING DATA PROGRAM

The machining data program calculates process times for machining operations and documents the feeds and speeds for operator instructions. These values are to be used in conjunction with manual times and allowances in the time standards program to set standards for machine shop operations. (Figure 3)

The program determines the ideal speeds and feeds by using values recommended in the machining data file. The program selects feeds and speeds after considering the material used, tool, machine specifications, dimensions of raw and finished workpiece, etc. When the ideal speeds and feeds are not available due to machine limitations, the program allows you to select alternative speeds and feeds. This is an automatic procedure when the machine specifications have been included in the data file. The machining operations included in the program are drilling & milling and turning (single point tool).

Figure 3

```

M TYPE OF MACHINING .<H=HELP> ?
N ARE CUTTERS THE SAME <Y,N> ?
N TYPE OF MILL <H=HELP> ?
SIM LENGTH FACTOR <1, 2, 3, H=HELP> ?
1 LENGTH ?
6 DEPTH PERPENDICULAR TO THE AXIS (WIDTH) ?
2 CUTTER DIA ?
5 NO. OF TEETH ?
8 TOTAL DEPTH CUT PARALLEL TO THE AXIS ?
2. CUTTER MATERIAL <S, C, H=HELP> ?
C

*****
SPEEDS AND FEEDS FOR MILLING

      CUT      SPEED      RPM      DEPTH      FEED      TIME
      *      FT/MIN      INCHES      IN/TOOTH      TMU IPM      TC EFF
R   1         312        238        0.2000        0.0075        950. 14.3        23.88
SIM TYPE OF MILL <:H=HELP> ?
SIM LENGTH FACTOR <1 , 2 , 3, H=HELP> ?
1 LENGTH ?
4 DEPTH PERPENDICULAR TO THE AXIS (WIDTH) ?
1 CUTTER DIA?
3.5 NO. OF TEETH ?
6 TOTAL DEPTH CUT PARALLEL TO THE AXIS ?
1 15 CUTTER MATERIAL <S, C, H=HELP> ?
C

*****
SPEEDS AND FEEDS FOR MILLING

      CUT      SPEED      RPM      DEPTH      FEED      TIME
      *      FT/MIN      INCHES      IN/TOOTH      TMU IPM      TC EFF
R   1         325        354        0.1500        0.0080        550.17 17.0        10.64
    FEED RATE SELECTED = 5,0000 (SET 5.0000)

```

## THE WELDING PROGRAM

The welding program contains four basic files: Joint descriptions, electrode descriptions or specifications, the welding method or procedure, and the manual elements involved. We enter the appropriate information in each file that is associated with our operation. Examples from each file are found in Figures 4 and 5.

In order to create a welding process time, we only need to identify the joint code, and the method code (the method specifies the electrode). The program then processes the information in its files to calculate the arc time (Figure 6) and the manual time. The result is reported out in a format that may be converted into a suboperation and placed in the data base.

Both the machining data program and the welding program are options in the sense that even without them, the analyst can determine process time by a manual formula, and enter those times in a suboperation, or directly in the time standard.

The creation of most suboperations with the computer program is, initially, slightly less time consuming than with the manual methods. However, as the data base is built up, more and more reference to existing suboperations will reduce the need for creating new method descriptions from scratch.

Figure 4

```

IDENTIFICATION          : PT1S.1-0-5/16
OUTPUT TO PRINTER ? N

JOINT TYPE              : FILLET
OVERWELD (IN)           : 0.000
LEG 1 EXCL. OVERWELD (IN) : 0.313
LEG 2 EXCL. OVERWELD (IN) : 0.313
GAP (IN)                 : 0.000

X' COMMAND (H-HELP) ? LM
IDENTIFICATION          : ALL
OUTPUT TO PRINTER ? N

IDENTIFICATION          : FILLET
OUTPUT TO PRINTER ? N

METHOD TYPE             : NON-GROOVE
TOTAL NO, OF PASSES     : 1
ELECTRODE               : 1E7018-06FF-0
VOLTAGE                  : 24
CURRENT                  : 225

IDENTIFICATION          : 1E701B-06FF-0
OUTPUT TO PRINTER ? N

ELECTRODE TYPE          : ROD
MAX CURRENT (A)          : 225.100
MIN CURRENT (A)          : 225.00
DEP RATE AT 225.0 A(LB/HR): 4.87
DEP RATE AT 225.0 A<LB/HR): 4.87
ROD WEIGHT (LB/FT)       : 0.108300
RESTOCK COUNT            : 23
EFFECTIVE LENGTH (IN)    : 12.00

```

Figure 5

COMMAND &lt;L, C, E, H=HELP&gt; ? L

1	PREPARE & STRIKE	MANUAL- SHIP	32001	300.0000000
2	PREPARE & STRIKE	MANUAL- SHOP	32002	1300.0000000
3	PREPARE & STRIKE	SEMI - AUTO- SHIP	32003	3.0000000
4	PREPARE & STRIKE	SEMI - AUTO- SHOP	32004	1425.0000000
5	PREPARE & STRIKE	AUTO- SHIP	32005	5.0000000
6	PREPARE & STRIKE	AUTO- SHOP	32006	6.0000000
7	PREPARE & STRIKE	GOUGE- SHIP	32037	37.0000000
8	PREPARE & STRIKE	GOUGE- SHOP	32038	38.0000000
9	CHANGE ELECTRODE	MANUAL- SHIP	32007	71.0000000
10	CHANGE ELECTRODE	MANUAL- SHOP	32008	250.0000000
11	CHANGE ELECTRODE	SEMI - AUTO- SHIP	32009	9.0000000
12	CHANGE ELECTRODE	SEMI - AUTO- SHOP	32010	12680.0000000
13	CHANGE ELECTRODE	AUTO- SHIP	32011	11.0000000
14	CHANGE ELECTRODE	AUTO- SHOP	32012	12.0000000
15	CHANGE ELECTRODE	GOUGE- SHIP	32039	39.0000000
16	CHANGE ELECTRODE	GOUGE- SHOP	32040	40.0000000
17	DESLAG	MANUAL- SHIP	32013	13.0000000
18	DESLAG	MANUAL- SHOP	32014	590.0000000
19	DESLAG	SEMI - AUTO- SHIP	32015	15.0000000
20	DESLAG	SEMI - AUTO- SHOP	32016	885.0000000
21	DESLAG	AUTO- SHIP	32017	17.0000000
22	DESLAG	AUTO- SHOP	31018	18.0000000
23	DESLAG	GOUGE- SHIP	32041	41.0000000
24	DESLAG	GOUGE- SHOP	32042	42.0000000
25	WIRE BRUSH	MANUAL- SHIP	32019	19.0000000
26	WIRE BRUSH	MANUAL- SHOP	32020	540.0000000
27	WIRE BRUSH	SEMI - AUTO- SHIP	32021	21.0000000
28	WIRE BRUSH	SEMI - AUTO- SHOP	32022	810.0000000
29	WIRE BRUSH	AUTO- SHIP	32023	23.0000000
30	WIRE BRUSH	AUTO- SHOP	32024	24.0000000
31	WIRE BRUSH	GOUGE- SHIP	32043	43.0000000
32	WIRE BRUSH	GOUGE- SHOP	32044	44.0000000
33	RESTOCK	MANUAL- SHIP	32025	25.0000000
34	RESTOCK	MANUAL- SHOP	32026	89.0000000
35	RESTOCK	SEMI - AUTO- SHIP	0	0.0000000
36	RESTOCK	SEMI - AUTO- SHOP	0	0.0000000
37	RESTOCK	AUTO- SHIP	0	0.0000000
38	RESTOCK	AUTO- SHOP	0	0.0000000
39	RESTOCK	GOUGE- SHIP	32045	45.0000000
40	RESTOCK	GOUGE- SHOP	32046	46.0000000
41	SET UP	MANUAL- SHIP	32031	1.1000000
42	SET UP	MANUAL- SHOP	32032	1.0330000
43	SET UP	SEMI - AUTO- SHIP	32033	1.1000000
44	SET UP	SEMI - AUTO- SHOP	32034	1.0330000
45	SET UP	AUTO- SHIP	32035	1.1000000
46	SET UP	AUTO- SHOP	32036	1.1000000
47	SET UP	GOUGE- SHIP	32047	1.1000000
48	SET UP	GOUGE- SHOP	32048	1.1000000
49	WELD LENGTH PER ARC-STRIKE (SEMI-AUTO)			1.5000000
50	EXTRA OVERWELD WIDTH FOR S G B R J SS GS BS RS JS			0.1250000
51	DEFAULT BASE METAL DENSITY (LB/FT3) FOR GOUGE ELECTRODE			489.5400085
52	COMMENTS			0.0000000
53	TEXT			0.0000000



Figure 6

```

XCOMMAND (H=HELP) ? CA
OUTPUT TO PRINTER ? N
. JOINT ID                : PT1S.1-0-5/16
METHOD ID                 : FILLET
LENGTH ( IN)             : 1
SHIP(I) OR SHOP(0)       : 0

=====

STEP 1: PT1S.1-0-5/16, 1.0 IN LONG, IN 1 PASSES (FILLET)
      0.58781 CUBIC INCHES PER FOOT

ELECTRODE      VOLT  AMPS WIRE SP.  TRAVEL SP  EL. CH.   ARC TIME (TMU)
-----
1E7018-06FF-0   24   225          5.9      0.1282    285.

=====

TOTAL MANUAL AND ARC TIME -      36.

```

Beyond the initial data preparation, the computer system is unequalled in terms of its ability to create time standards and the needed documentation for implementation. The facility for maintaining up-to-date data, making revisions, and accessing the files is far superior to any manual system of filing or using the data.

To accomodate the special needs of the shipbuilding industry -- with its large products encompassing many thousands of manhours -- there are a few enhancements to the programs that are either in place, in process, or planned. Briefly these include:

- A. Time Standard Summary - This feature is presently included in the software. Given specific ship component coding, it is possible to request a list of all standards on file that pertain to a given piece of work (a hull section, a deckhouse, or even the whole ship). The result is a title listing of all the standards involved, a statement of the number of standards involved, and the total standard hours for the defined work. In other words, a summary time for any specified code or construction level of the ship.
- B. Real Time Work Standards - This enhancement is planned, and involves the modification of a given time standard for real time planning purposes - and/or for estimating.

Since the shipbuilding industry has not traditionally used engineered time standards, we must carefully define the level of application to be used, and the method of using the standards. First we must realize that the time standard produced through MOST Computer Systems is a labor standard. This standard defines the time required to accomplish a defined piece of work when the operator is working at the 100% performance level, and when there are no unavoidable delays or non-work events.

- C. Maxi MOST - For measuring large scale fabrication and assembly operations.

## PRACTICAL APPLICATIONS OF MOST

Whether we want to modify the labor standard for performance or other factors, depends directly on the way we intend to use the standard. We need to identify the various areas of application for time standards. The following lists include most of the applications, divided in three basic shipyard functions.

### 1. INDUSTRIAL/MANUFACTURING/PRODUCTION ENGINEERING

- a. Methods Improvement
- b. Tool, Equipment and Machinery Evaluation
- c. Facility Layout, Flow and Workplace Arrangement
- c. Productivity Improvement Through Delay Identification and Elimination
- e. Manning - Balancing and Critical Path Determination
- f. Labor Incentives
- g. Make/Buy Analyses
- h. Long Range Facilities Planning

### 2. PRODUCTION

- a. Supervisory Control
- b. Manpower Distribution and Assignment
- c. Labor Performance Reporting and Analysis
- d. Productivity Improvement

### 3. PRODUCTION PLANNING, SCHEDULING AND CONTROL

- a. Labor Budgeting
- b. Shop Scheduling
- c. Critical Path Development

- d. Material Requirements Planning (when and where)
- e. Estimating

Now let's take a look at the various outputs of MOST Computer Systems - and see where they are used in the application areas.

1. MOST Program -

Work area layouts. The defined work area incorporating the space, workplaces, objects, tools, equipment and carriers used to perform specific work.

Method steps. The exact description of an element of work in the work area.

These outputs can be directly used for applications 1a, 1b, and 1c.

2. The Data Base program -

- o Suboperations. A group of method steps required to complete a specific task or operation at a work area.

- o Combined Suboperations. A group of suboperations required to produce a specific component, subassembly, assembly or product.

- o Process Time. The time required for a machine or process monitored by an operator. This calculation is usually determined by time study or from special tables or from the welding and machining programs.

These outputs can be directly used for applications 1a, 1b, 1c, 1e, and 1g.

### 3. The Time Standard Program -

Time Standards. Combined suboperation and appropriate process time(s) plus allowances for personal time (P = washroom, coffee break, etc.) human fatigue (F) unavoidable delay (D = Foreman instructions, multi-operator interaction, safety meetings, etc.) and process efficiency (e.g., machine operating variations, welding process modifications, etc.). The time standard defines the time required to perform a predetermined amount of work at the 100% performance level.

These outputs can be directly used for applications

(1) all, and (2) all.

### 4. Application Standards -

A modification of a time standard to account for real world situations. Application standards are derived by applying temporary (revisable) allowances to time standards. The temporary allowances account for such events as crane or material handling delays, material shortage delays, crew imbalances, actual labor performance (i.e., performance will improve from 20% to 60% over the first five ships of a class) and "uncertainty" factors for estimating purposes. (Uncertainty factors would include evaluations of increases or decreases in work content of a new ship in comparison to a ship for which there are existing standards, and expected patterns of material flow, etc.)

These application standards are used for applications Id, 1e, 1h, 2b, 2c, 2d, and 3 all.

We are now considering an enhancement to the time standard program, to permit a second level (or even a third level) of time standards -- the application standard -- to be developed within the program by using appropriate allowances. The proper application of the mass update program will permit us to maintain the application allowances at whatever real world state we wish. Under any circumstances, we must use these allowances manually in order to arrive at standards that are usable by the planning and control functions of the shipyard.

5. An enhancement in the process of being finalized (and it is really a further development of MOST Systems is Maxi MOST.

In spite of the fact that MOST Systems of standards development gives us the ability to produce valid standards for long cycle and non-repetitive operations with a minimum investment in analyst time, there is always the call for something even faster. It is not unexpected that members of the shipbuilding industry are in the vanguard of those companies seeking such a goal.

Toward that end, H.B. Maynard and Company has been working with two clients to develop an advanced version of MOST for use in "heavy" industry. One client is a manufacturer of large trucks, and the other is a shipyard.

The system is called Maxi MOST, and utilizes five basic sequences: three for manual activities, and two for material handling. In Maxi MOST, the index values are ten times larger than those used for Basic MOST, Thus implying that each method step in Maxi MOST would cover ten times the work as each step of Basic MOST -- and thus be ten times faster to apply. It is probably more realistic to say that the application speed of Maxi MOST is about five times faster than that of Basic MOST

The system itself has been developed and applied manually for about six months, and has been fairly well debugged. At this point in time, the computer version has been developed, and testing was initiated just over two weeks ago. It is anticipated that the computer module for Maxi MOST will be fully debugged and ready for general use before the end of this year.

During the debugging period, evaluations are being made to define the levels of accuracy that can be expected -- relative to the work cycle time and the balancing time of the system. There is no doubt in our mind that Maxi MOST has great potential in the majority of shipyard construction and erection operations.

In summation, MOST Computer Systems is a powerful tool for the shipyard -- one that enables us to set engineered time standards for any yard

operation rapidly and accurately. The use of the computer enables us to file, review, adjust, and synthesize a vast amount of data within a short time period - and with relatively little manpower. It provides the ability to produce updated and effective end use documents on command. Finally, it provides a solid basis for linkage to an overall management information system. It provides the essential element of sound labor reporting, evaluation and control that has the major impact on shipyard cost.

With reference to the Japanese success story, they are in fact using most of the classical I.E. functions, such as: methods improvement, development of special jigs and fixtures, process flow improvement, production standards development, and line balancing. The work is being done through the services of "Production Engineers" assigned to each major area of the shipyard -- men with degrees in naval architecture or engineering.

Further, the Japanese have had the advantage of building large numbers of similar type ships. One result is that they have been able to refine their "historical" standards and key them to such parameters as total weld length, feet of pipe, and total weight. Since those parameters have some significance on similar ships, they have also developed the special factors and allowances selected in their operations -- and they use those predetermined standards for planning, estimating, budgeting, etc.



The MOST Computer Systems programs that we have described give us in the United States the opportunity to develop predetermined standards specifically designed for the onesy-twosey type of operations that dominates our shipbuilding. It also provides a much more effective means of identifying those nonproductive operations and those delays that we can exert effort to eliminate, and make radical improvements in our productivity.

As a result, we are getting the hands on experience needed to prove the value of MOST Computer Systems in the shipyard. Through the SNAME SF-8 Panel Industrial Engineering Program, the potential uses of MOST Computer Systems in the shipyard are being tested and applied. By the end of the current program year, it is expected that the data development and program refinement work will be complete. There will be sufficient data to validate the expectations, and to define the planned applications of labor standards in shipyard operations for next year's program.

## INTERACTIVE PARTS DEFINITION PROJECT

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Newport News, Virginia

### ABSTRACT

The concepts and history behind this project that will permit IREAPS shipyards to introduce interactive graphics economically into their production environment are addressed. Since the project is near completion, the uses and benefits of the deliverables are examined. On the technical side, the project accomplished some key interfaces and shipbuilding refinements.

### Background:

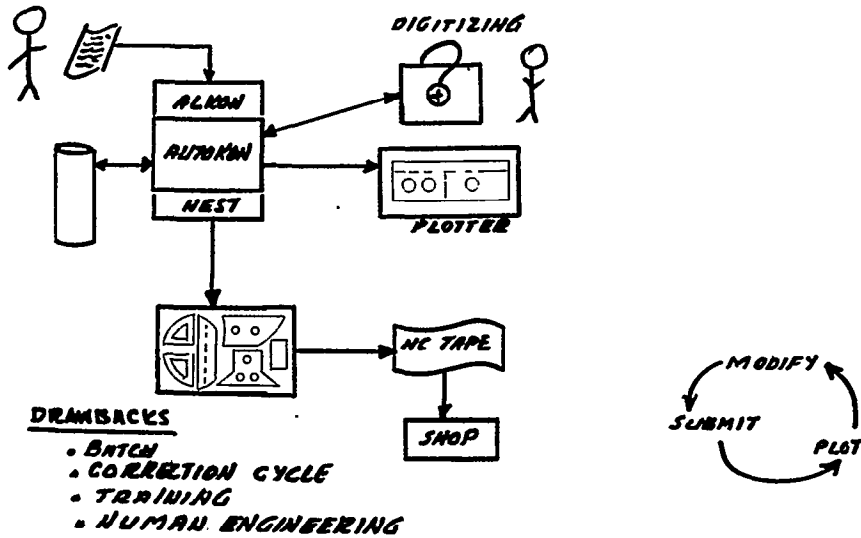
Interactive Part Definition (IPD) represents an idea which grew out of the necessity to improve current Mold Loft techniques for parts generation and nesting. As shown in figure 1, the draw backs include batch oriented programs, time consuming correction cycles, and difficult training and human factor considerations. Figure 2 shows the proposed system using interactive graphics techniques to eliminate correction cycles by on-line response and increase productivity by improved human engineering.

IPD has the following requirements which were defined by NNS and the IREAPS participants:

- Hardware/software package to allow users to perform real time definition of their application with visual (Graphic) output and build up a digital model of the definition at the same time.
- Must be portable and capable of being updated and expanded independently of the vendor.
- Provide a general tool to be available for future graphics projects within U. S. Shipbuilding.
- Dedicated computer hardware to provide response to support interactive graphics.
- Capable of direct interface to AUTOKON/SPADES/STEERBEAR Systems.

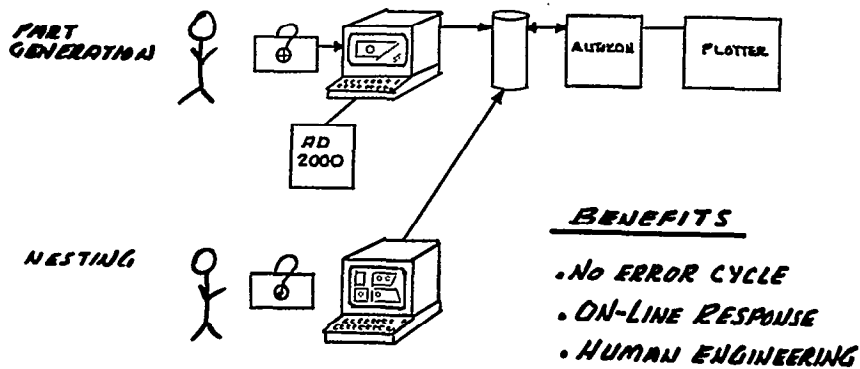
# MOLD LOFT CURRENT TECHNIQUES

1



# MOLD LOFT PROPOSAL

2



The AD2000 software system was selected as the principal element of the system. The implementation schedule for the project is shown in figure 3 and 4 as modified by vendor schedules and changes in schedule.

#### Status:

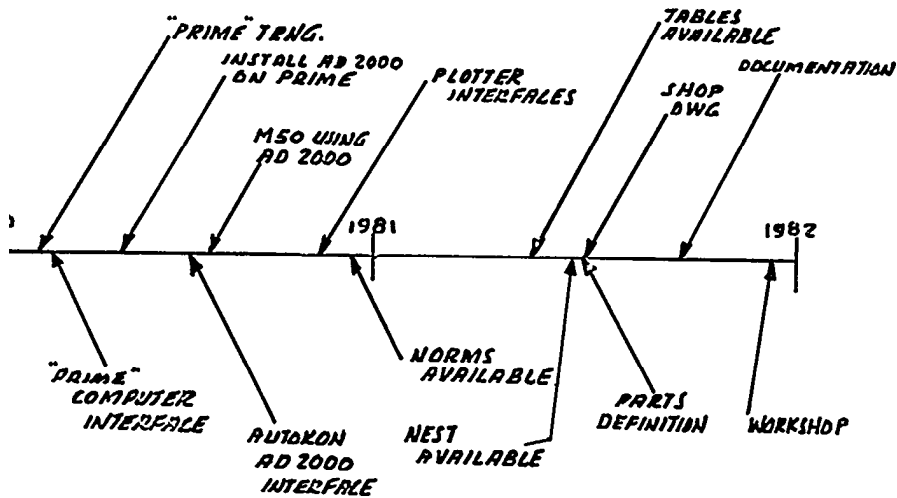
This two year IREAPS project is in its final stages of completion and has been reported on at several previous IREAPS Synposiums. The project has successfully integrated computer hardware and software to produce a graphics system tailored for the definition, nesting and annotation of ship structural parts. It furthermore permits an IREAPS member to implement this system at a relatively low cost.

#### Hardware Interfaces

##### 1. Prime 750 Mini-computer

The Prime 750 was obtained to house the Parts definition Software. It was interfaced to the Honeywell 6000 main frame at Newport News via a 9600 baud link. This was done contractually by Prime, but the testing and debugging was largely done by NNS. The Prime runs as a slave to the H6000 by using the Honeywell GRTS protocol. This interface allowed us to pass files, command files (Prime jobs) and listing files from the H6000 to the Prime. Likewise H6000 job files could be passed to the H6000 from the Prime for execution. An example of this would be in sending AUTOKON parts from the H6000 to the Prime or AD2000 source listings to the H6000 page printing system.

3



4

# PROJECT PLAN PHASE II

	MONTH OF COMPLETION FROM START OF PHASE
* • ISSUE PURCHASE ORDERS	1
* • PRIME TRAINING	3
* • DEFINE DATA SPECIFICATION	5
* • AD 2000 INTERFACE	5
* • WRITE HOST ROUTINES	7
* • HARDWARE/SOFTWARE INSTALLATION	7
* • RJE INTERFACE	7
* • AD 2000 INSTALLATION	9
* • AD 2000 TRAINING	10
* • MINI SEND/RECEIVE	12
* • REFINE NEST	20 + 4
* • REFINE NORMS	15
* • TABLES	19
* • SHOP DRAWING CAPABILITY	20
* • REFINE PARTS DEFINITION	20
• DOCUMENTATION	23 + 4
• WORKSHOP	24 + 4

\*INDICATES WORK ALREADY COMPLETE

2. Graphics Terminals

Both slow speed data terminals and Tektranix 4014's (9600 baud) were connected to the Prime. These were installed on phone lines and modems, allowing for installations in 5 buildings around the yard. While higher speeds are desirable, no distance limitations exist in this configuration.

3. Gerber 1200 Plotter

We could gain access to this remote plotter via the Mohawk 2400.

4. Benson-Varian 9222 Plotter

This 22" wide, electrostatic plotter was interfaced remotely via a 9600 baud connection. We experienced some interface problems between the Prime and the 9222 controller. Compensations for this fact had to be placed in the interface software. This plotter is now settling down as a production tool.

5. Altek Digitizer

The Altek is a send only device that connects to the Prime via a 9600 baud line. We did experience some parity problems which have been solved. This digitizer is now used in production.

6. Mohawk 2400

This remote job entry computer is attached to the Prime via a 9600 baud line. It is likewise attached to the Honeywell 6000. It runs as a slave to the Prime and the H6000, using the GRTS protocol to talk to both. This

allows us to switch between both systems from our Mold Loft where it is located. This nicety came as the result of a good contract negotiation with Prime. Via the M2400, we can submit jobs to the Prime and receive back plot/punch data on tape or printed listings. This becomes our means to direct plots from the Prime to the Gerber 1200 plotter which is tape driven.

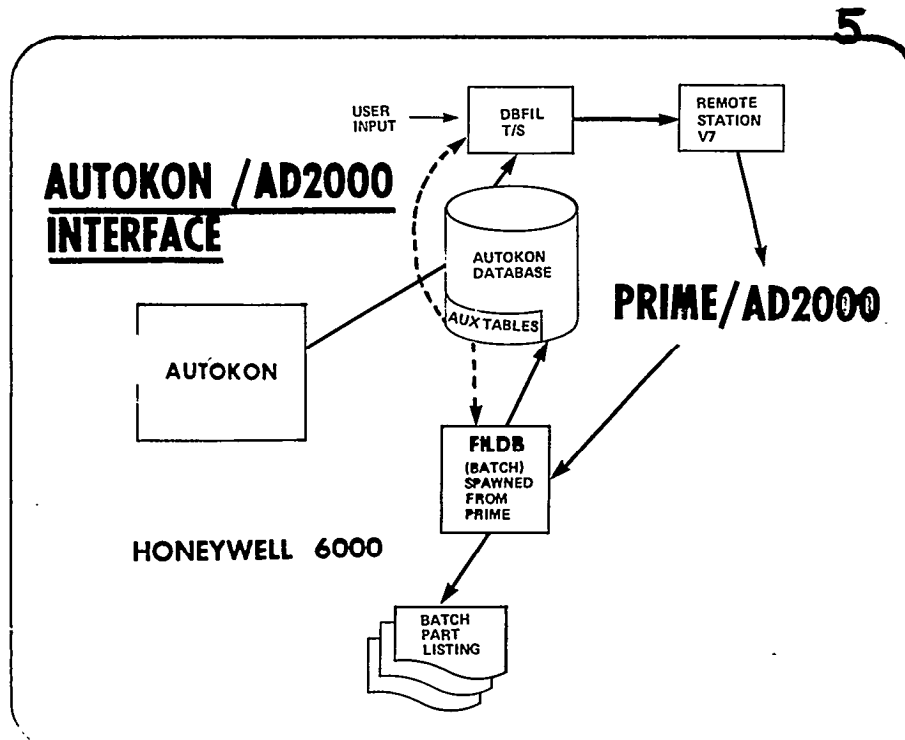
#### Software Interfaces:

1. AUTOKON/AD2000 Interface (AUTOKON SIDE) See Figure 5

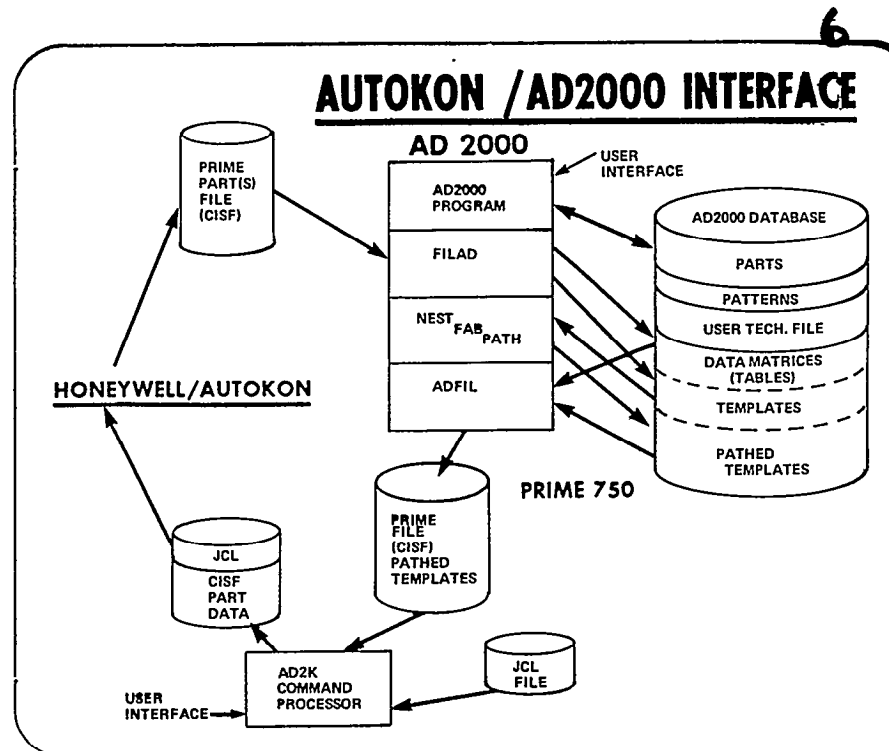
The Parts Definition project viewed AD2000 as a peripheral to a major Ship NC System such as AUTOKON, SPADES, STEERBEAR, etc. Therefore an interface to these systems was essential. At NNS we interfaced to AUTOKON, however the approach is the same to other NC Systems and much of the software can be used independently of the NC-System. Our first effort was to pass part geometry to AD2000 and back. Later we passed tabular data which encompassed all data in the AUTOKON database, including geometry. Figure 5 shows how data is extracted from AUTOKON via the interactive program DBFIL and sent to the Prime. FILDB on the other hand receives data from AD2000 on the Prime and stores it in the AUTOKON database. It is non-interactive. AUX Tables are used to determine the relationship between AUX codes in AUTOKON and Levels/Attributes in AD2000. FILDB and DBFIL are 80% AUTOKON dependent and 20% Honeywell dependent.



5



6



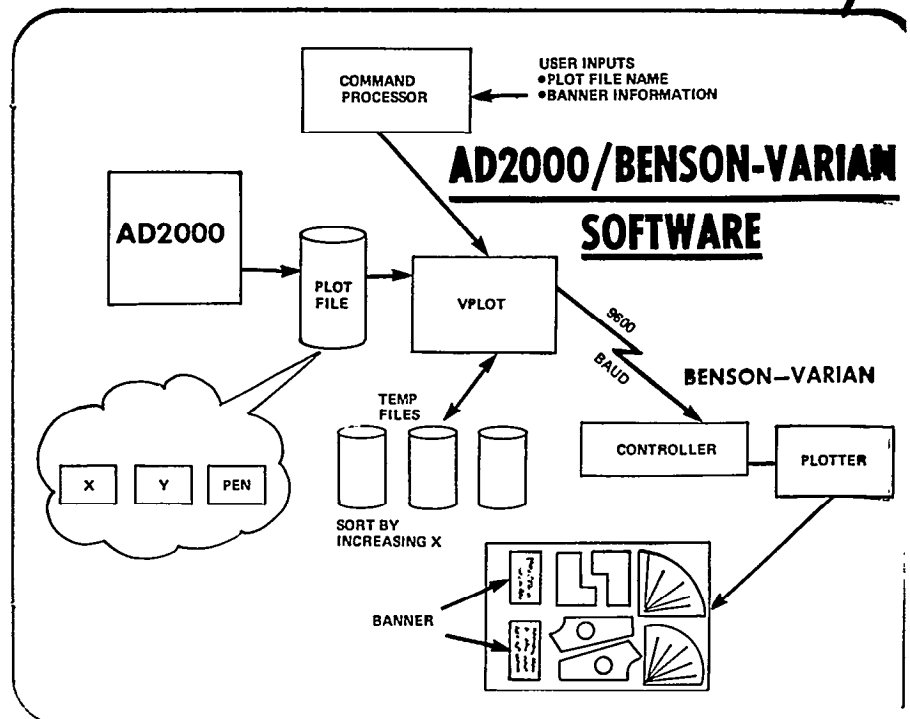
2. AUTOKON/AD2000 Interface (AD2000 Side) See Figure 6

On the Prime the data received from AUTOKON appears as an ASCII card image file called a CISF (Computer Independent Serial Format). This file can handle integer and floating point numbers with 10 digit accuracies as well as text, attributes and accounting information. The CISF was designed as a possible data exchange vehicle for shipyards who implement this system. A FILAD module in AD2000 reads the CIF and stores the data as either Templates (parts) or Data Matrices (Tables) in the AD2000 Database. Likewise the ADFIL module of AD2000 extracts data from the AD2000 database and creates a CISF file to be sent to AUTOKON on the Honeywell. Unlike FILDB and DBFIL, ADFIL and FILAD are 100% computer independent, being part of AD2000 itself.

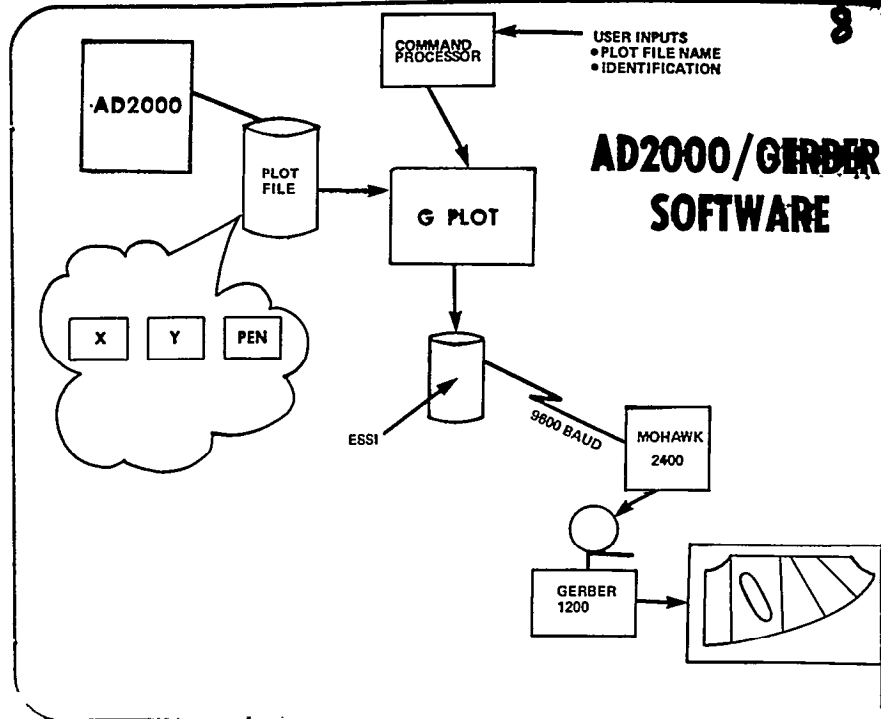
3. AD2000 - Benson Varian Interface See Figure 7

AD2000 produces a binary plot file consisting of an X, Y coordinate and a pen code. A program was written called VPLLOT to process this plot file and transmit it to the Benson Varian plotter. Since the plotter is a raster type, VPLLOT must sort all geometry by increasing X values. It also provides banner information. The complete installation and development of this interface was done by Dominion Business Computers Inc. who did a good overall job for us. VPLLOT is thus proprietary to Dominion, however available from them. We have found that plot files can be large and should be eventually plotted at night. While 9600 baud appears to be too slow, the software is solid.

7



8



4. AD2000 - Gerber Interface      See Figure 8

Since the Gerber 1200 at NNS already accepts ESSI formatted geometry for plotting, we chose to convert the AD2000 plot file to ESSI. The GPL0T program was written to do this and at the same time provide some user controlled optimization of pen movement. The ESSI file created by GPL0T on the Prime is then transmitted to the Mohawk 2400 for plotting on the Gerber. Although this approach works, we are unable to take advantage of the arc generation features of the Gerber since AD2000 currently only produces straight line segments. This results in large ESSI files with often some very small pen moves.

IPD Refinements:

1. NEST/FAB/PATH

This module is a second attempt to develop a module in AD2000 to provide a capability to nest ship parts, add fabrication details (bridges, leadins, etc.) and develop an optimum cutting path. The work has been done by Manufacturing and Consulting Services, Inc., the home of AD2000 under contract. The first attempt only provided for nesting. NNS personnel then developed a specification that would provide a more capable tool for part nesting, fabbing and pathing. MCS has just recently delivered their first version of this module and it will require some interactive evaluation - refinement cycles before it is acceptable.

2. Data Matrices                      See Figure 9

The Data Matrices capability was added to AD2000 by NNS to provide it the ability to use and manipulate tabular data similarly to the way AUTOKON does. With this capability the AD2000 user can manipulate Data Matrices interactively (Edit, Create, Copy, Delete, etc). He can move values from Data Matrices into and out of AD2000 variables. An interface to the GRAPL language (Geometric Macros) allows GRAPL to use the Data Matrices similarly to the way AUTOKON NORMS use tables or lists. Although similar to AUTOKON Tables. Data Matrices are indeed independent of AUTOKON.

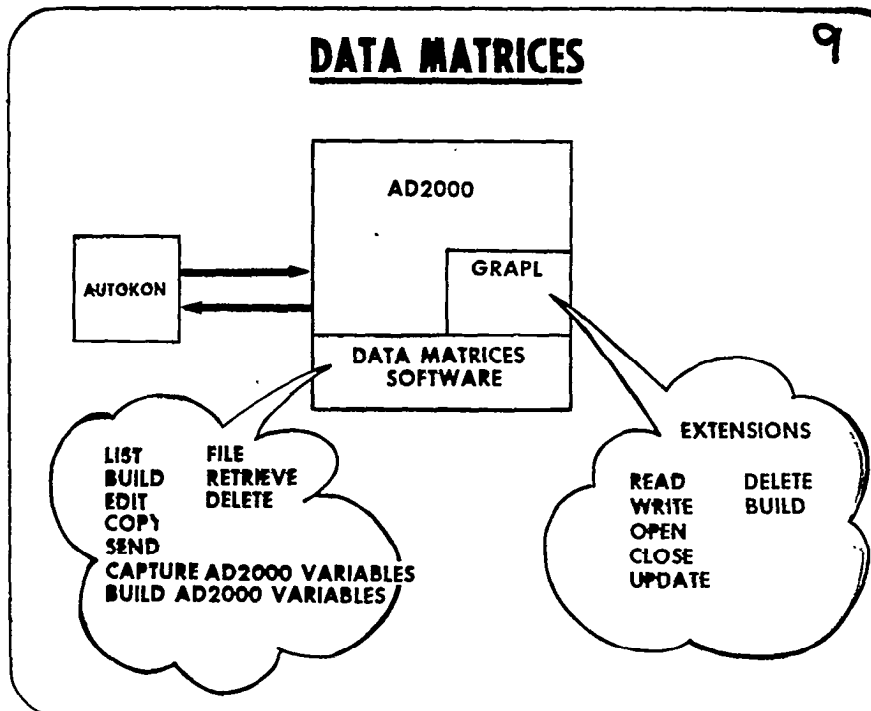
3. AD2000 - Digitizer Interface                      See Figure 10

To allow real time digitizing into AD2000, we took advantage of the fact that the Prime allowed multiple terminals to be connected to the same program simultaneously. We also took advantage of the micro processor in the ALTEK which allowed the user to program each of the 8 cursor buttons. Data can thus be sent to AD2000 from the cursor or from an alpha numeric keyboard.

Inputs to AD2000 are switchable from the ALTEK and Tektronix 4014 by use of the 'Control Q' character which simply tells AD2000 which line to read from. AD2000 sends all of its normal outputs to the 4014. With this setup, the user can run AD2000 from the ALTEK by programming menu choices into the cursor buttons and watching the resultant geometry appear on the 4014. Figure 10 shows sample cursor

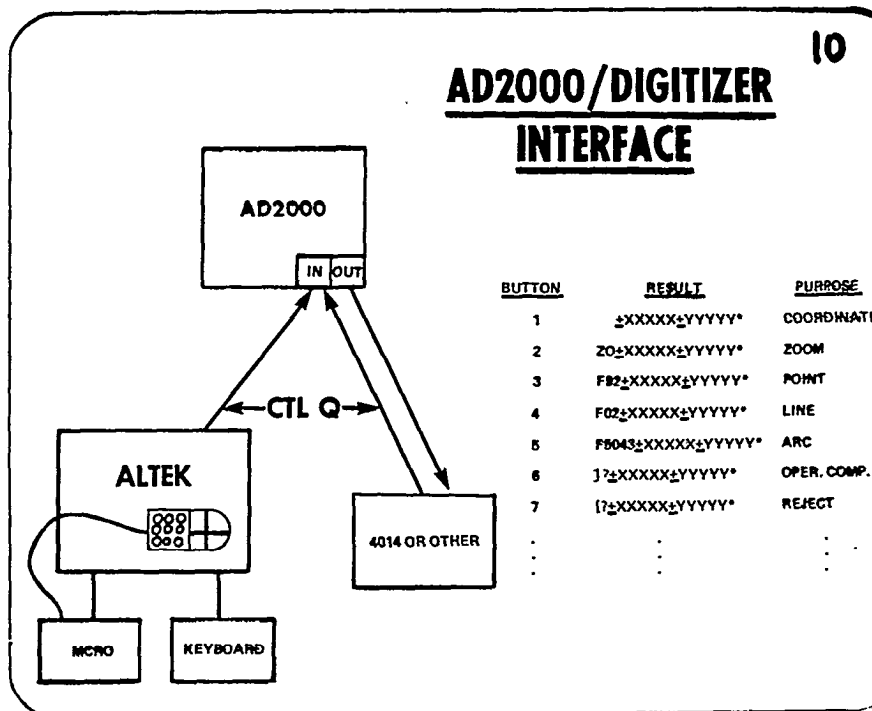
## DATA MATRICES

9



## AD2000/DIGITIZER INTERFACE

10



button definitions. We have found this to be a very fast way of capturing geometric data, it is quickly accepted by users and requires minimal training (8 buttons to choose from). It also yields 5 digit accuracy. Since AD2000 only allows counter clockwise arcs, we developed an ability within AD2000 to define arcs in either direction which is essential for continuous digitizing. Although this implementation is highly productive, we feel it can be greatly enhanced when the users begin to write and call out GRAPL programs via the cursor buttons.

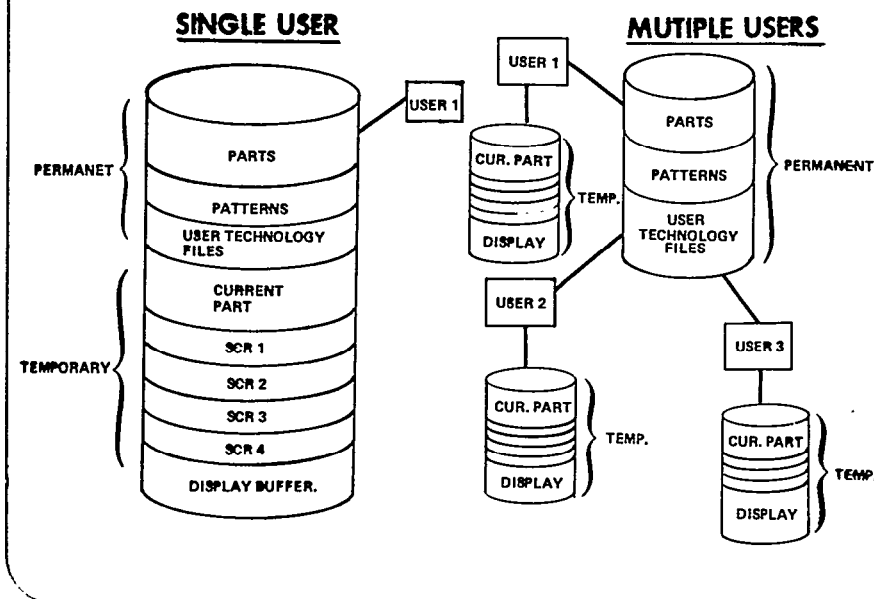
4. Multi User Databases See Figure 11

AD2000 is delivered allowing only one user to access a database at a time. However only a portion (Parts, Patterns and User Technology Files) retain permanent information. The rest of the database is temporary storage for the current session. NNS devised a scheme such that each user would be assigned his own temporary storage area and share the permanent area with other users via an attach-access-detach sequence. This has worked quite nicely since it was installed early in the IPD project.

5. GRAPL See Figure 12 and 13

GRAPL is a Graphics Macro language supplied by MCS that permits the AD2000 user to write parametric driven routines using a graphics language for standard geometric shapes. It is a Family of Parts tool similar to AUTOKON NORMS in its purpose. Figure 12 gives an example of one GRAPL program used to create three different results. When

## DATA BASES



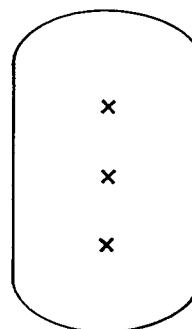
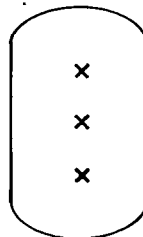
## SAMPLE GRAPL PROGRAM

12

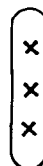
RESULT 2

TEXT

RESULT 1



RESULT 3

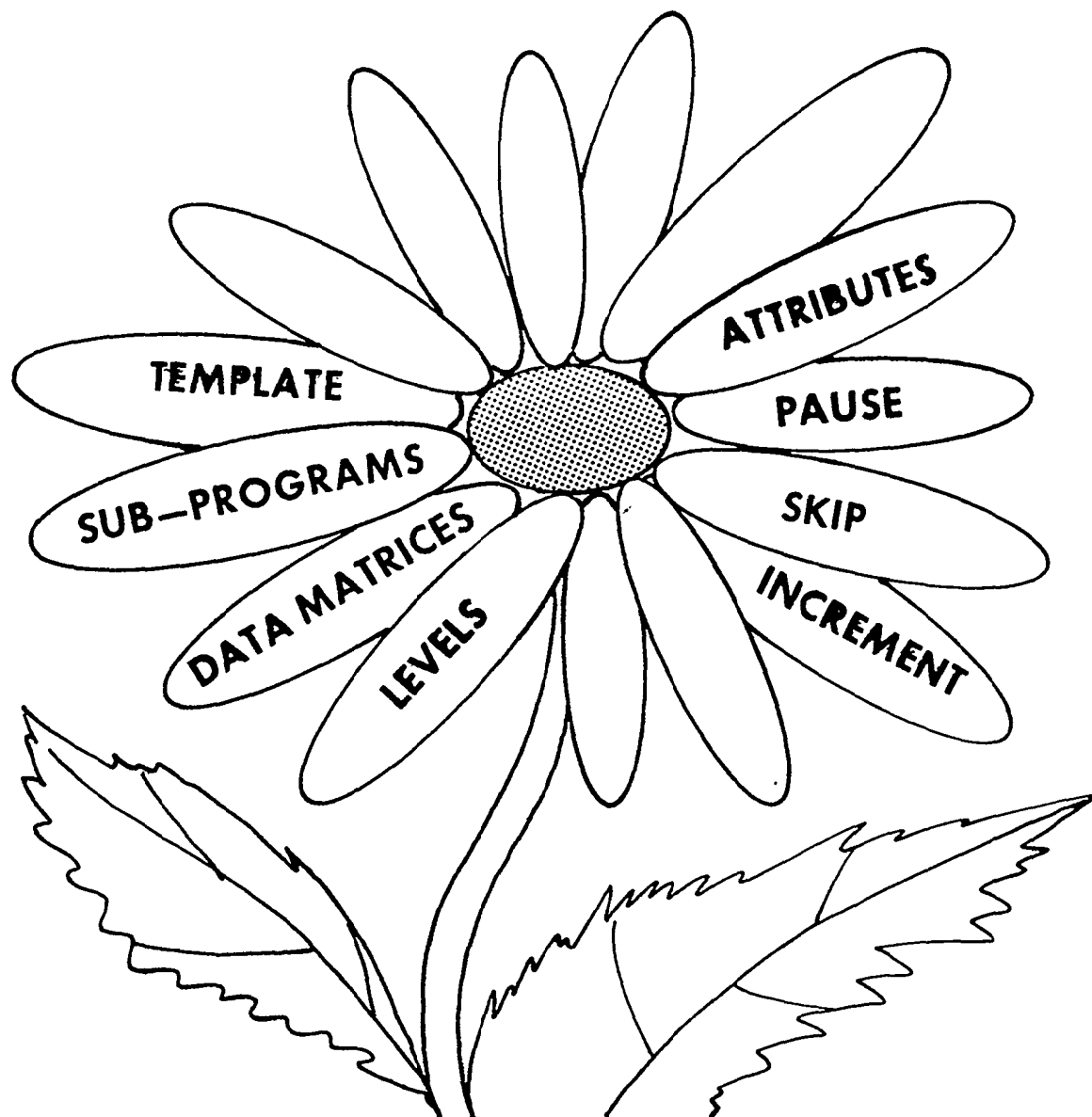


```

1 SIZE, ARG(5)
2 REMARK/HOLE 102 SIMULATED NORM KWP
3 REMARK/ARG1, ARG2, ARG3-CNTX,Y,Z
4 REMARK/ARG4, ARG5-DEPTH, HEIGHT
5 PARAMS/KEY IN 5 ARGS,5,2 'XCEN',2, 'YCEN',2, 'ZCEN',
6 2, 'DEPTH',2, 'HEIGHT', IDUM,ARG(1), STAT
7 REMARK/DO CALCULATIONS
8 PT1-POINT/ARG(1), ARG(2), ARG(3)
9 PT2-POINT/ARG(1), ARG(2)+ARG(5)-ARG(4), ARG(3)
10 PT3-POINT/ARG(1), ARG(2)-ARG(5)-ARG(4), ARG(3)
11 RAD1-ARG(4)/2
12 CIR1-CIRCLE/CENTER, PT2, RADIUS, RAD1, COANC, 0, ENDANG, 180
13 CIR2-CIRCLE/CENTER, PT3, RADIUS, RAD1, COANC, 180, ENDANG, 0
14 LIN1-LINE/RIGHT, TANTO, CIR1, RIGHT, CIR2
15 LIN2-LINE/LEFT, TANTO, CIR1, LEFT, CIR2
16 STOP
    
```



## IPD GRAPL ENHANCEMENTS



obtaining AD2000, NNS developed contractual specifications that would make GRAPL more useful to Shipbuilding than it was. These include

- a. Templates - Templates (ship parts) can be retrieved and soon filed in the database.
- b. Subprograms - A GRAPL program can be stopped and resumed after other AD2000 tasks are performed, including the execution of another GRAPL program.
- c. Data Matrices - Discussed previously.
- d. Levels - GRAPL programs can create geometry on any level desired.
- e. Attributes - Attributes can be assigned to entities by GRAPL.
- f. PAUSE - SKIP - INCREMENT - The user can exit and resume a GRAPL program, skip executable statements or increment a statement at a time.
- g. Cursor - A GRAPL program can ask the user to select geometry by using the cursor device.

On the whole NNS pushed MCS to develop an interactive graphics language so that a user organization could write its own graphics applications without dependence on a computer programmer. We at NNS see many users for GRAPL in our future developments.

## AN APPROACH TO SUCCESSFUL SHIPYARD PLANNING AND SCHEDULING

Stephen M. Knapp  
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### ABSTRACT

Critical paths, "I-J" nodes, and activity duration are all words of the network designer. All are usually foreign to the shipyard planner, and in general, shipyard planning personnel tend to shy away from the networking approach to ship construction planning. Networking, however, can be used to plan, and subsequently schedule, the production work orders required to complete the construction of any vessel, regardless of its complexity.

The fundamental approach to successful shop production planning and scheduling using networking techniques that have reduced planning time dramatically are described.

Two basic criteria for the planning and scheduling network are "simplicity" and "accuracy". Simplicity is concerned with the creation, development, and maintenance of a production plan. Accuracy defines the manner in which the plan reflects the actual construction of the vessel in question.

This is not intended to be another discussion of some new and fabulous planning tool, or an indepth presentation of S A M E theoretical concept to improve your planning department, It is to demonstrate an actual, proven approach to planning which has been used successfully on a number of vessels, and to briefly describe the techniques and software tools used in that approach.

The planning approach presented is the result of a serious, concentrated effort on the part of the planning staff of SPAR Associates, to improve the plans and schedules of SPAR's client shipyards. The approach centers around a no-nonsense, pragmatic discipline whose primary objective is to produce reliable and accurate production workorders, scheduled in such a manner as to represent the actual building philosophies of the shipbuilding industry.

SPAR's planning approach continues to mature, fed by experience derived from planning all or part of six individual vessels over the past 12 months, In addition, yard generated plans for four other ships were reviewed, using SPAR's "Standard Planning Guide" as criteria for the analyses.

Most shipyards deal with a finite number and specific type of vessel that they normally bid on. Planning becomes somewhat more direct, in that planning personnel tend to become accustomed to the exact nature of the ship, and eventually develop an informal standard for plans and schedules within that yard, SPAR, however,

must deal with a larger number of ship types, and seldom gets the luxury of learning the internal workings of the client. yards. As a result, SPAR's planners had to replace the yard's planning standards with a clearly defined planning discipline to insure the integrity of their product. This discipline has become so accurate that certain client. yards have actually begun to implement. the disciplined approach in lieu of their traditional planning methodologies.

To establish a basis for successful planning, certain preliminary requirements have to be defined. In short., a "planning-plan" must. exist to guide the planners through the many paths necessary to realize the full potential of their experience, use of computer tools, and the continual evaluation of the vessel. Therefore, the planning procedures must spell out such items as kick-off meetings, planning milestones, and standard documents to be prepared,

The initial development of the plan should begin as early as possible within the construction cycle of the ship. Preferably, the planning effort should begin when the initial request. for quote was presented to the yard, resulting in a schedule of the major development and construction milestones, A good preliminary plan at this stage should contain roughly 10% of the total estimated number of workpackages that will comprise the final plan, This first published schedule thus forms the backbone of the overall Vessel's direction, in that all of the yard's resources can be focused on the ship. By completing t-his high-level schedule within weeks of the RFQ, all departments can review their own ability

to perform. Engineering can view the timing of the drawing release sequence, Material can evaluate any potential delivery problems for specification items, and Management will be afforded an up-front assessment of the impact on the yard. This schedule may also contain "canned" activities to direct the development of the quote by indicating the required involvement of Production, Engineering, Material, and other departments,

Once Management decides to bid on the contract, Planning must swing into high gear to complete the detailed production schedules in time to support the construction. Here is where the discipline of planning takes its full form. Prior to start of work, Planning must prepare schedules to support drawing release, material procurement, shop loading, steel erection, and the full complement of workpackages required by Production. Everything must be covered,

Shop fabrication and assembly of steel and systems must be defined. Testing schedules must be ready for review by Quality Control. All construction milestones must be prepared and reviewed by Production and Management.

This approach is definitely bold, calling for planning to be in control of the yard. To realize this effort, planning must understand all of the yard's constraints, be flexible and responsive to the needs of production, and be capable of adapting its techniques to accommodate the changing climate of the contract, driven by the customer, engineering, and the environment of the year. To accomplish this feat, the shipyard must have set policies governing

planning and all affected areas subject to the planning department , The planning department must. function from strict procedural guidelines to insure that their plans are accurate and the schedules are workable. To insure this, planning must. have a discipline which must focus on the following points.

1. Individual planners, both SPAR's and the client yard's, have their own "technique" towards the preparation of the plan. Therefore, the discipline must. establish the complete guidelines to eliminate redundant work, insure the integration of segments planned by different people, and to clearly define each person's responsibilities.
2. The resultant plan and schedule must be easily visualized by all departments within the yard.
3. The systems or product work breakdown structure must. be recognized, understood, and accepted by all departments within the yard,
4. The resultant plan and schedule must be flexible to allow for customer or engineering changes, preoutfit versus normal outfitting construction, recovery planning, and resource constraint. evaluation.

- 5, Finally, a standard "Planning Document" must be created to provide for historical analyses, plan and schedule maintenance, and as a basis for the planning of future vessels of the same or similar type.

The planning methodology centers around the use of an "I - J" node network. After dividing the ship into standard zones, each zone is encoded into its nominal form and placed onto SPAR'S PERT-PAC system, under the Micronet library. An example of a nominal zone would be one cargo tank with activities defined to accommodate the construction of any such cargo tank. A complete cargo midbody can thus be networked by repetitive "calls" to the Micronet library to transfer in the cargo tank, changing such variably defined items as the zone number, lead steel unit number, or the user defined "increment" number. After the transfer, this tank can be customized by removing excessive activities or by adding those activities particular to this cargo tank.

The PERT-PAC system's Micronet library permits the definition of activities in terms of variables;. Thus, a workorder may be defined as a combination of ship's account, ship's zone, and some arbitrary digit, combined for a six <6> digit workorder number. For example, an activity on a Micronet might read "AAZZW" with an account number assignment of 248. Upon transfer of this micronet to the master network, the ship's zone and the extra digit would be specified to complete the definition of this workorder. For example, TRANSFER (12345) Z=25, W=8 would generate a workorder of



"248258", Since subsequent transfers would reference a different zone, no duplication of 248258 would occur.

The planning discipline insures that these zone transfers will not generate redundant or conflicting activities, by dictating the workorder numbering scheme and the I-J node numbering approach. Duplicate workorder definitions are flagged as an error and are not loaded to the master network. The discipline states that each zone placed onto the Micronet library be self-contained. Each zone construct, therefore, must contain activities for Engineering, Material procurement and control, Fabrication/Assembly, Installation, component testing, and the necessary network links to systems tests and master network control activities, such as sea trials or delivery.

While the rules for workorder and node numbering are rather detailed, the careful use of the discipline by the planning group has demonstrated that one vessel can be planned by numerous people with no problems surfacing when the pieces are integrated into a final network. Even system5 testing, which must be "fed" by numerous installation activities throughout the network, does not create a problem, since a single-activity *Micronet* is Created, and its account number is left as a variable, 80 When a planner needs to accomodate systems tests for account 123, an additional *Micronet* transfer is merely coded: TRANSFER <1154893> A=123. If some other planner has previously supplied this systems testing activity, the PERT-PAC system will reject the latter definition. The

planner is thus assured that his required testing activity is in place, whether or not his transfer actually placed it into the master network.

Planning by zone is a very important part of this approach. The total network picture need never be drawn. Instead, graphical presentations of the nominal zone micronets and an overview sketch of the master network provides enough visibility into the plan to make it workable. The capabilities of the PERT-PAC Micronet facility thus augments the natural planning methods associated with zone oriented production. The combination of network philosophies, the PERT-PAC computer system, and the written procedures for the planning endeavor insures that the resultant schedules are accurate, simplified, and complete.

SPAR Associates has defined a planning approach based on:

- \* NETWORKS - for design and visualization of the plan
- \* PERT-PAC - for maintaining the network and generating schedules
- \* DISCIPLINE - to insure accuracy and simplicity of the entire planning operation

The discipline, being the controlling element, has received the most attention in terms of development and review, While the

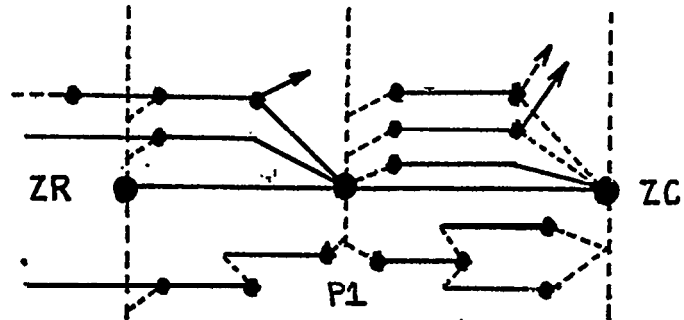
Standard Planning Guide cannot be considered complete, its Continued use for planning the client's vessels provides an excellent field-testing environment,

### Complete Plans

- \* Engineering drawings
- \* Material Requirements by CWBS and Zone
- \* Fabrication of Steel and Systems
- \* Assembly of Steel and Systems
- \* Steel Erection
- \* systems installation
- \* Testing by Zone, System, Compartment
- \* Major Milestones

# PERT-WC Micronets

I-----C-



- \* Variable Definitions
- \* Repetitive Use Without Duplicated Packages
- \* Easily Removed for Substitutions
- \* can Be "Cloned" for Alternative Planning
- \* Automatic Node Linking to Form Chains  
(Steel, Erection)

## Standard Planning Guide: Table of Contents

---

1, 0	Introduction and Terminology
2, 0	Planning and Networking Philosophy
3 , 0	Shipyard Data Requirements
4, 0	Deliverable Items
5, 0	Manpower and Facilities Loading Option
6, 0	Labor Control Option
7. 0	Planning and Networking Techniques
7, 1	Engineering
7. 2	Material
7, 3	Preoutfitting/Postoutfitting
7, 4	Testing activities
7, 5	Steel Erection Sequence and Control
7. 6	Auxiliary Machinery
8, 0	Master Network Content and Construction
9 , 0	Milestones and Holidays

### APPENDICES

A	Sample List of Micronet Number Assignments
B	Sample Micronet Pictorials
C	Planning Services Pricing
D	Sample Planning Data Forms

### FIGURES

4, 0, 1	Sample PERT-PAC Major Milestone Status Report
4, 0, 2	sample PERT-PAC Critical Path Report
4, 0, 3	Sample PERT-PAC Activity Listing
4, 0, 4	Sample PERT-PAC Activity Schedule Barchart (Monthly Time Scale)
4. 0. 5	Sample PERT-PAC activity Schedule Barchart (Weekly Time Scale)

S, P, G, : Table of Contents, continued

5.0. 1	Sample Manpower Requirements Report
<del>6.0.1</del>	Labor Performance By Project Work Breakdown Structure
6.0. 2	Labor Performance by Trade Group
6.0. 3	labor Performance By Work Center
6.0. 4	Labor Performance By Ship Zone
6.0. 5	Project Performance Trend Report
7.1. 1	Engineering Activitiy Requirements
7.2. 1	Material Activity Requirements
7.3. 1	Sample Node Numbering Scheme
9.0. 1	Sample Milestone List

## Ship's Planning Documentation

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SPAR will deliver to the client shipyard a document describing the general planning approach used, problems encountered, brief analysis of schedules, constraints encountered or used, and required maintenance necessary to support the network. The documents vary from ship-to-ship, both in context and scope, depending primarily upon the complexity of the vessel. The following outline presents the major points in the Ship's Planning Documentation.

### 1, Pre-Planning

#### A. Review of shipyard management structure

- 1, Planning Department
- 2, Production Departments
- 3, Engineering/Drawing Office
4. Material Procurement and Control
5. Project Management

#### B. Observations regarding the vessel

- 1, Steel and systems complexity
- 2, Urgency of needed schedules
- 3, Quantity/Quality of planning done by yard
4. Extent of customer changes, past and current
- 5, Extent of pre-outfit installation to be done
- 6, Extent of pre-outfit painting to be done
- 7, Extent of equipment modularization to be done

#### C, Analysis of existing planning on this vessel

- 1, Strength of existing workorder numbering scheme
- 2, Quality of zone assignments
3. Extent of planning performed to-date
- 4, Any observable problems

## II. Steel

### A. Workorder identification

1. Fabrication
2. Assembly
3. Erection
4. On-ship Welding
5. Miscellaneous support

### B. Micronet configuration

### C. Pre-outfit "hot" and "cold" configuration, if applicable

### D. Pre-outfit paint considerations, if applicable

### E. Erection sequence constraints

1. Primary; build direction
2. Secondary; geographic relationships
3. Design; partial ship movement, planned delays, etc

### F. Problems

## III, systems

### A. Workorder identification

1. Purchased items
2. Shop fabrication
3. Shop/ship assembly
4. Ship installation
5. Pre-outfit installation

### B. Micronet configurations, by ship's zone

### C. Installation sequence constraints

1. Supported material
2. Supported engineering
3. Steel structure; bulkheads, overheads, etc
4. Planned delays



#### IV. Testing

##### A. Zone or Unit testing

1. Workorder identification
2. Scope
3. Problems

##### B. Independent tank testing

1. Workorder identification
2. accuracy based on knowledge of hull structure
3. Accuracy based on required support testing equipment
4. Problems

##### c. systems testing

1. Workorder identification
2. Micronet configuration
3. Testing plan
4. Problems

#### v. Network/Schedule Maintenance

##### A. Change of build direction

##### B. Change of pre-outfit quantity/quality

##### C. Error detection and correction

1. Bad durations or lead times
2. bad activity relationships
3. Loops

##### D. Schedule problems

1. Delivery too late
2. Missed milestone dates
3. Late material or engineering
4. Failed tests
5. Customer changes
6. Engineering change notices

PLANNING AND SCHEDULING SHIP CONSTRUCTION  
SUBJECT TO LIMITED RESOURCES

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PREFACE

The over-riding concern in shipbuilding today is how to increase productivity. However, attention instead should be focused upon improving management. policy, Quality of goods and services produced and the improvement. of production operations from a controlled learning experience should be management's primary goals. By concentrating on these in increased productivity will be a by-product.

The learning process, however, requires a basis from which management, can evaluate past. performance and develop a program for avoiding failures and improving upon the **successes**. This basis does not evolve by happenstance, It must be the result of deliberate, careful and reasonably detailed planning and a means for capturing actual performance against the plan,

This discussion addresses the vital need to consider and accommodate t-he impact of limited resources (manpower, **floor** space, crane capacity, etc.) to the planning Problem. Often ignored by planning, resources, if not available in sufficient quantities, or not applied properly, will most. definitely lead to higher costs and longer production schedules.

## I.0 Introduction

-----

In a well-managed company, the determination of resource requirements is essential both to insure that sufficient resources are available, and that excess resources do not burden overhead costs. Resource planning is a cross-check between the resource assignment and scheduling processes.

The analysis of resource availability can determine if planned schedules are indeed achievable. The basic sources of data needed to develop resource requirements are the resource estimates and planned schedules of work. Resource analysis accuracy depends upon the level of detail at which the resource estimates and schedules have been developed,

Information typically available at the early stages of a contract are the major milestone *dates* (start, launch, de delivery, etc.) and the bid estimates, usually at the major account work breakdown *level* of the project. Overall department or trade breakdown detail may also be available at this time. With this information, and with the aid of historical curves, preliminary resource requirements (primarily manpower) can be derived and will be as accurate as the degree to which the historical curve actually conforms to the new contract situation. Unfortunately, such is not normally the case. Many shipyards currently develop initial production schedules and resource requirements at the very *minimum* levels of detail.

Modern computerized techniques have proved that a smooth loading curve is not always possible as may be attempted manually. Consider, for example, the case where there are critical time periods where deviation from schedule *is* not possible *in* order to meet contracted delivery dates. If manual smooth loading were adopted under such circumstances, there would result an immediate impact upon the delivery and the plan would begin as a losing situation without anyone realizing the eventual problem until too late.

A condition like that *above*, if repeated on a number of contracts, too often leads to a general lack of confidence in a plan even before a project begins (negative attitude on the part of Production?).

## 2.0 the Work Package Approach

For a company that has adopted the work package concept, the ideal level of information would be the entire set of work packages, complete with resource estimates and schedules. There is, at this level, no need to use historical curves per se because the overlaying of resource requirements for each work package will generate its own profile, as will be discussed in Section 4.0.

In the manual process of resource loading, the bar chart format (see Figure 3, 0.2) is generally chosen, but interrelationships are difficult to maintain in an orderly way. Therefore, it is almost impossible to comprehend the various alternatives that can be used in attaining the ultimate goal of scheduling within the limits of available resources.

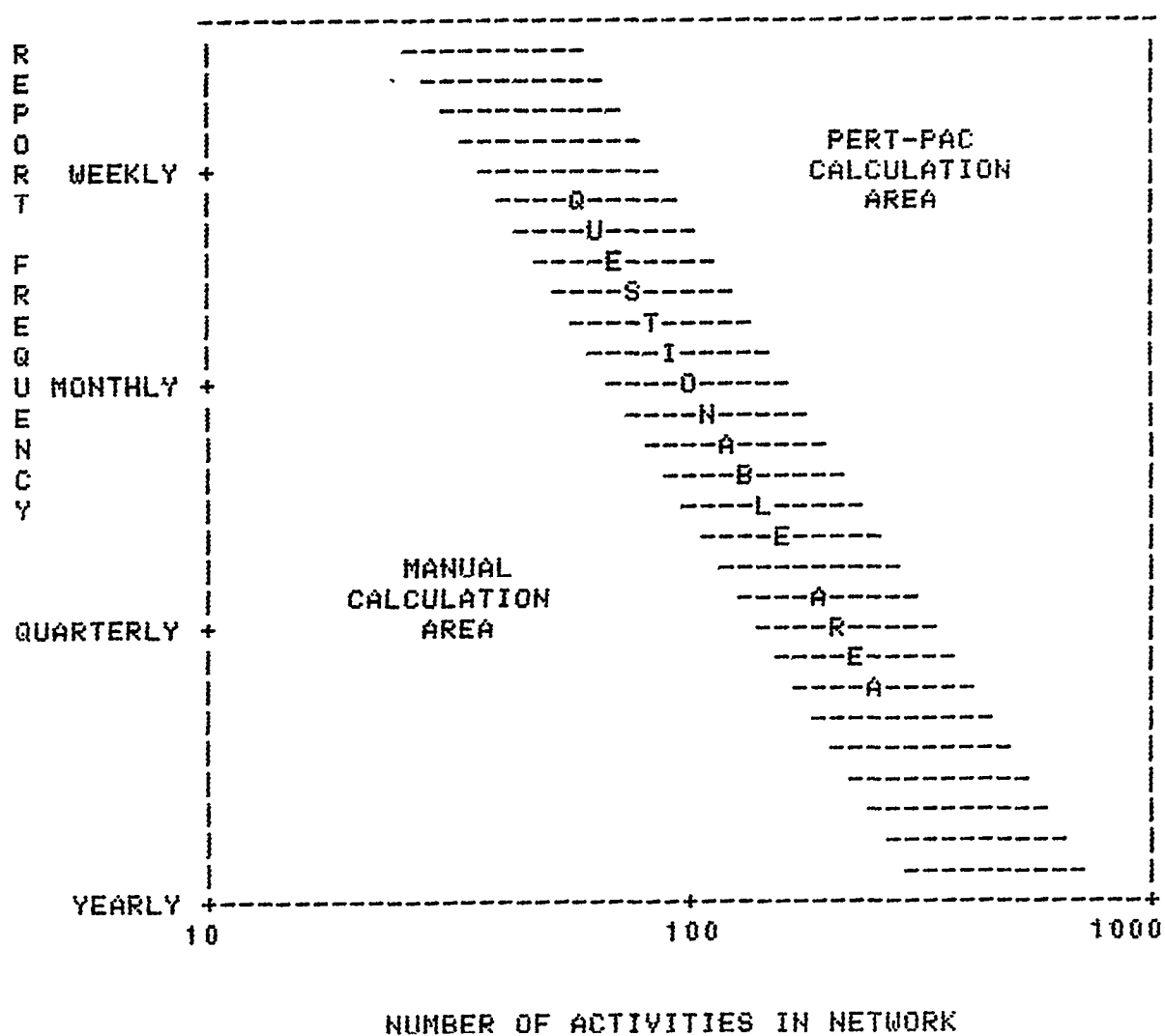
Once a project has been planned and scheduled, the planning effort should not stop. Management likely will always need to evaluate cost and schedule performance on a continuous basis and make necessary decisions to re-plan and re-direct available resource in the best ways possible.

If an average project involves some 5,000 activity and management demands accurate and timely reports but is reluctant to expand overhead staff, it is unlikely that a solid plan with realistic resource loading and practical production schedules can be developed.

The computer, however, can be exploited quickly and cost effectively. Software is available to expedite the detail scheduling process accurately and in an orderly way using such methods as the critical path network technique. And, if resource estimates can be applied to the same level of work breakdown (activities), very accurate and meaningful resource requirements can be easily determined to form a rational basis for the ultimate project scheduling.

The choice between using a computer or manual method is mainly a question of cost and convenience. A definitive answer is difficult for small projects, but larger ones, or once requiring an interplay between multiple projects, can derive significant benefits from a computerized approach. Factors which influence the decision to computerize include the number of activities, the number of schedule performance reports expected, the content to which resources involved are to be analyzed, and the desired output format. Figure 2.0.1 illustrates the relative breakeven points for given numbers of activities and the reporting frequency.

FIGURE 2.0.1: Chart Of Computerized Versus Manual Methods Selection



### 3.0 Network Scheduling

-----

Network scheduling (critical path method) is a planning technique that allows schedules to be developed from appropriate start/stop dependencies between activities. See Figure 3.0.1 for a sample network illustration.

The advantage of using the critical path method for scheduling is that it provides a means to logically develop all work within a project and to establish the proper sequences of activities. Networks generate real work priorities needed later to maintain schedules. As work is actually completed, priorities can change, and management must continuously strive to expedite the more critical work.

For non-critical activities, the method determines slack time available, within which time activities may be started and completed without any further restraint by the network configuration.

Figure 3.0.2 illustrates a sample bar chart result of network scheduling. Note that the critical path method has established early start dates for all activities; those with slack time available (shown with dashed lines) are free to start any time within this slack time frame, provided they do not finish any time later than the date at the ends of their slack periods. Figure 3.0.3 presents the manpower loading if all activities started at their earliest start dates, regardless of the slack time available,

Ideally, any project should be expedited on the earliest possible start date for all work involved; this better insures that any delays will have minimum effect upon the ultimate completion of the project. However, what may well make *this* ideal impractical is whether or not these non-critical activities have sufficient resources to all start at their earliest start dates,

Even if resources are available, applying them all at the earliest possible time may not be cost effective, either in the short or long run. Practically speaking, however, the ability to perform work at a constant level of manpower normally means lower costs. Erratic levels of manpower usually translates into excessive overtimes, unstable hiring requirements, low worker morale and all the attendant problems - and expenses. Hiring-and-firing policies lead to high employee turnover which, in turn, leads to poor product quality and higher costs.

Figure 3.0, 4 presents the manpower loading if all activities started at their latest start dates, any slippage whatever obviously leaves no room for recovery of the total planned project completion schedule.

Figure 3.0. 5 presents the range of possible rates of manpower expenditures permitted *within* bounds of the critical path scheduling. The object, thus, is to develop a rate consistent to meet final delivery schedules and to *minimize* overall costs,

If resources are limited, the least critical activities should be delayed until after the more critical activities have been completed and resources are available.

Clearly, additional efforts must be expended in the planning process to have schedules meet not only critical path, but also limited resource requirements.

FIGURE 3.0.1: SAMPLE CRITICAL PATH METHOD NETWORK

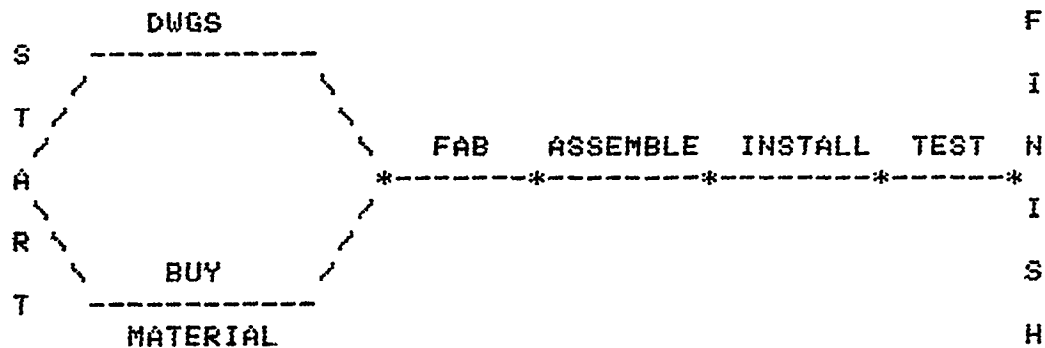


FIGURE 3, 0, 2

WORK PACKAGE SCHEDULES  
BEFORE  
LIMITING MANPOWER; IN OUTFIT

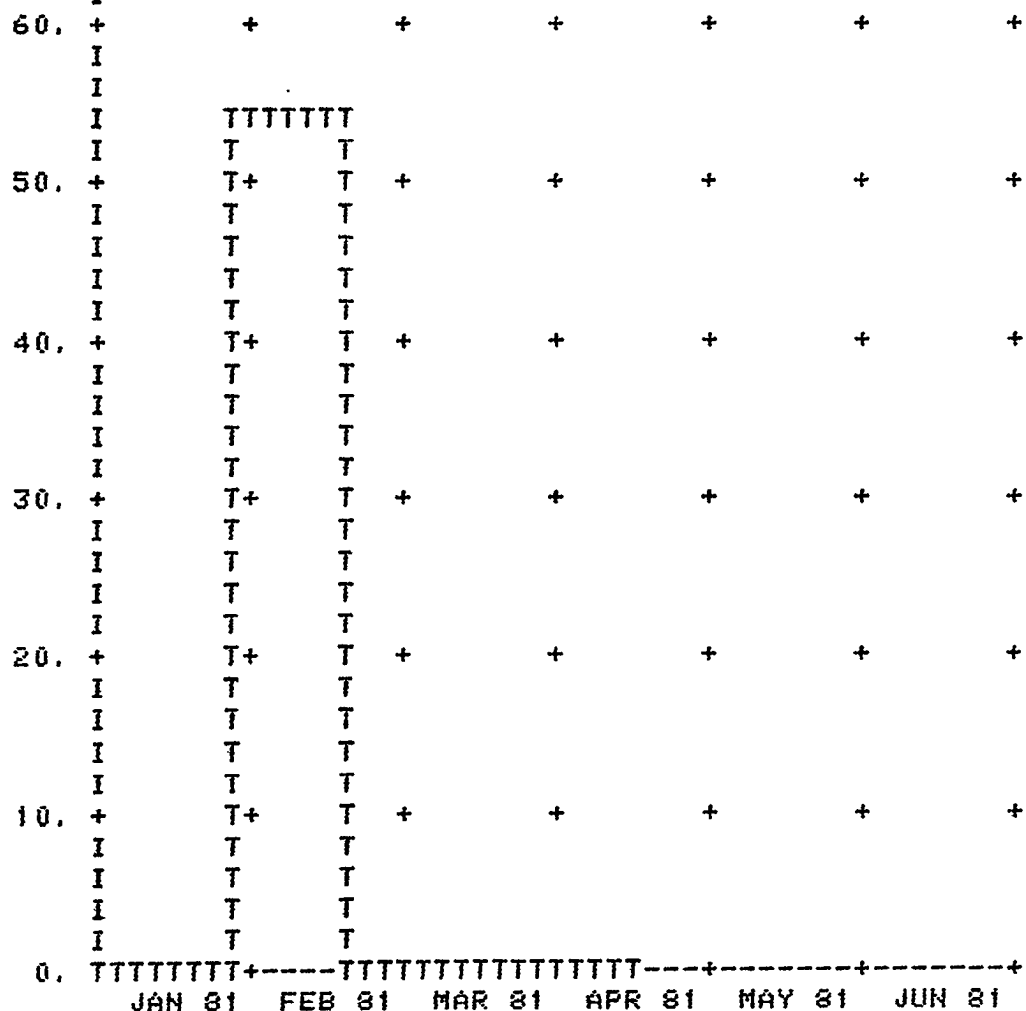
	JAN 81	FEB 81	MAR 81	APR 81	WC	PKG	HRS
+	+	+	+	+	+		
+	XXXXXX	-----	-----	-----	+	2 102110. SHOP ASSEMBLY	500.
+	XXXXXX	-----	-----	-----	+	2 102109. SHOP ASSEMBLY	500.
+	XXXXXX	-----	-----	+	+	2 102108. SHOP ASSEMBLY	500.
+	XXXXXX	-----	-----	+	+	2 102107. SHOP ASSEMBLY	500.
+	XXXXXX	-----	-----	+	+	2 102106. SHOP ASSEMBLY	500.
+	XXXXXX	-----	-----	+	+	2 102105. SHOP ASSEMBLY	500.
+	XXXXXX	-----	+	+	+	2 102104. SHOP ASSEMBLY	500.
+	XXXXXX	-----	+	+	+	2 102103. SHOP ASSEMBLY	500.
+	XXXXXX	-----	+	+	+	2 102102. SHOP ASSEMBLY	500.
+	XXXXXXXX	-----	-----	-----	+	3 103110. UNIT OUTFIT	650.
+	XXXXXXXX	-----	-----	-----	+	3 103109. UNIT OUTFIT	650.
+	XXXXXXXX	-----	-----	-----	+	3 103108. UNIT OUTFIT	650.
+	XXXXXXXX	-----	-----	-----	+	3 103107. UNIT OUTFIT	650.
+	XXXXXXXX	-----	-----	+	+	3 103106. UNIT OUTFIT	650.
+	XXXXXXXX	-----	-----	+	+	3 103105. UNIT OUTFIT	650.
+	XXXXXXXX	-----	-----	+	+	3 103104. UNIT OUTFIT	650.
+	XXXXXXXX	-----	-----	+	+	3 103103. UNIT OUTFIT	650.
+	XXXXXXXX	-----	-----	+	+	3 103102. UNIT OUTFIT	650.
+	XXXXXXXX	-----	-----	+	+	3 103101. UNIT OUTFIT	650.
+	+	+	+	+	+		
	JAN 81	FEB 81	MAR 81	APR 81			



80, + + + + + + +

FIGURE 3.0.3

MANPOWER LOADING WITHOUT LIMITS  
(Schedules In Early Start)



TOTAL MEN PLANNED

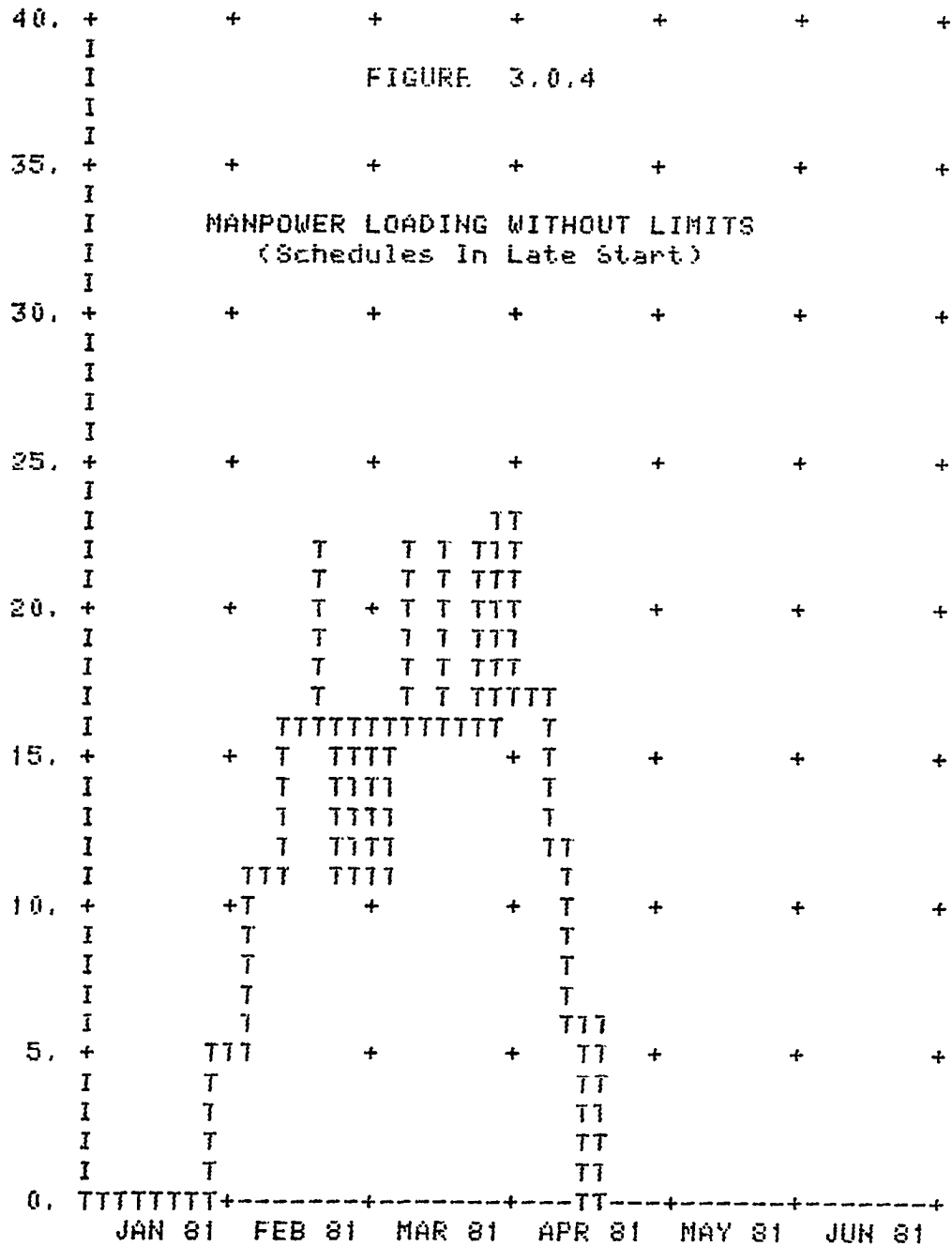
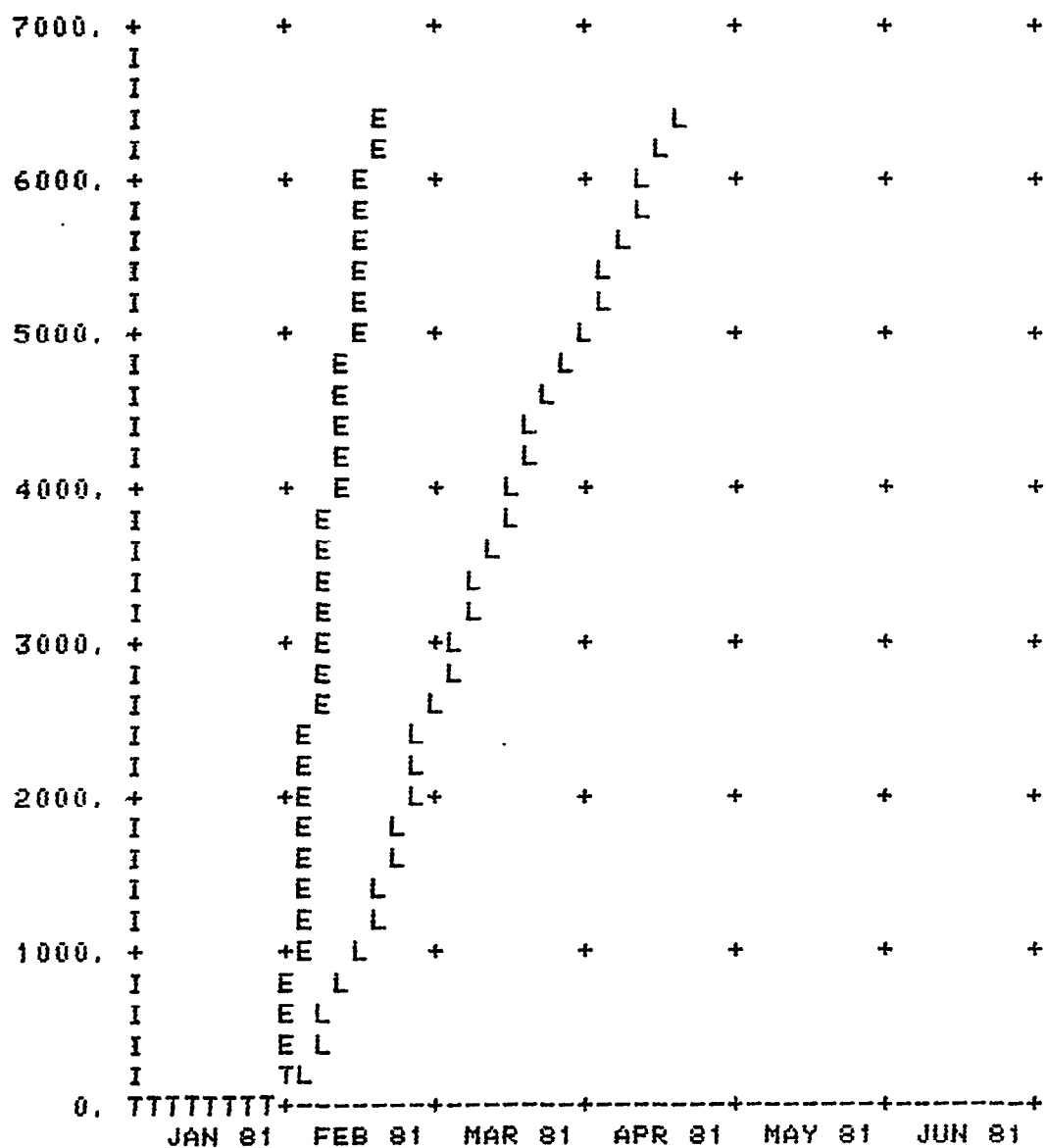


FIGURE 3.0.5

Range Of Possible Manpower Rates Of  
Expenditure

MANHOURS



#### 4.0 The Resource Allocation Problem

-----

A method to develop resource requirements is illustrated in Figure 4.0.1. By tallying the resources over the time periods that the activities are in process, the total resource requirements at all points in time can be estimated by assuming that resources will be expended at a constant rate over the time period of the activity. This constant expenditure assumption is valid for most practical purposes if activities are reasonably small and of short duration. Also, net effects from summing numerous activities tend to even out any local distortions that may arise whenever this assumption fails to match actual expenditures exactly,

Non-constant resource expenditures are also possible, but suffer the drawbacks of being too complicated for most planning applications. And, they do not contribute significantly to the overall accuracy of the scheduling if the activities are developed properly.

Once resources have been estimated for activities, the next problem is to establish overall limits to their availabilities. These limits may be applied to different types of resources (manpower, float-space, cranes, etc.) and made time-variable to better model expected conditions within the shipyard,

##### 4.1 Limiting Project Resources

-----

the resource leveling effort attempts to maintain all activity start dates as the early start dates developed by the critical path method of scheduling. This helps insure that any actual delays in schedules will have minimum impact upon the overall project completion schedule. In the resource leveling procedure, critical activities should be loaded first so that they consume resources first. The procedure then should continuously check whether resources are available to begin a new activity; if not, the activity must be delayed and its slack time reduced accordingly.

Under no circumstances should an activity be delayed beyond its computed slack time.

Figure 4.1.1 illustrates the manpower requirements subject to limited resources. Figure 4.1.2 provides a revised bar chart of activity schedules reflecting these adjustments,

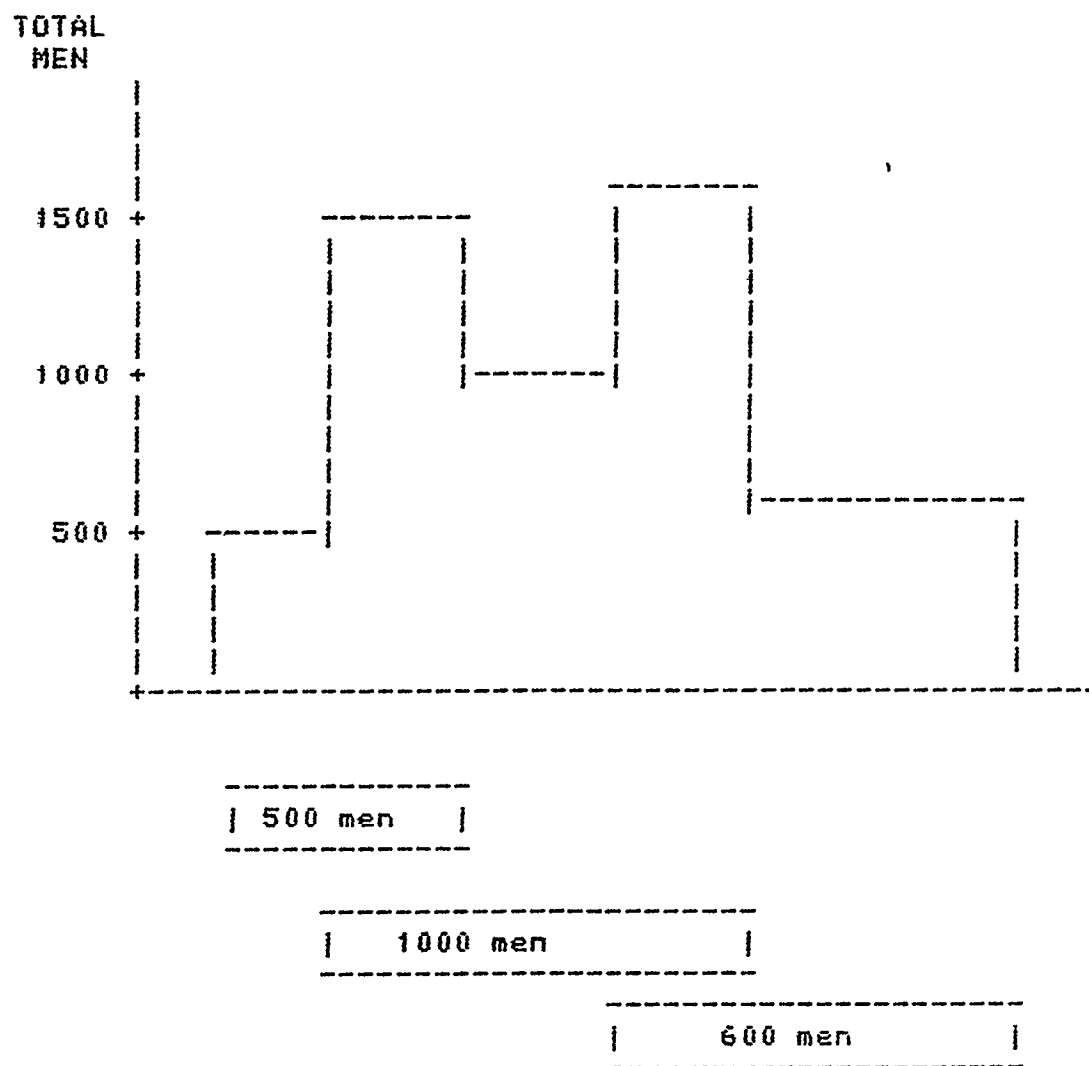


Figure 4.0.1: PERT-PAC Procedure For Developing Resource Requirements

TOTAL MEN PLANNED

40. + + + + + + +

I

I

I

I

35. + + + + + + +

I

I

I

I

30. + + + + + + +

I

I

I

I

25. + + + + + + +

I

I

LIMIT 22 MEN IN SHOP

I.....TTTTTTTTTTTTT.....

I

I

20. + T+ + T + + + +

I

I

I

I

I

15. + T+ + T + + + +

I

I

I

I

I

10. + T+ + T TTTT T + + +

I

I

I

I

I

5. + T+ + T T T T T T T T

I

I

I

I

I

0. TTTT TTTT +-----+-----+-----+-----+-----+-----+

JAN 81 FEB 81 MAR 81 APR 81 MAY 81 JUN 81

SAFETY MARGIN

FIGURE 4.1.2

WORK PACKAGE SCHEDULES  
AFTER  
LIMITING MANPOWER IN OUTFIT

	JAN 81	FEB 81	MAR 81	APR 81	WC	PKG	HRS
+	-----+	-----+	-----+	-----+	+		
+	XXXXX-----				+	2 102110. SHOP ASSEMBLY	500.
+	XXXXX-----				+	2 102109. SHOP ASSEMBLY	500.
+	XXXXX-----		+		+	2 102108. SHOP ASSEMBLY	500.
+	XXXXX-----		+		+	2 102107. SHOP ASSEMBLY	500.
+	XXXXX-----		+		+	2 102106. SHOP ASSEMBLY	500.
+	XXXXX-----		+		+	2 102105. SHOP ASSEMBLY	500.
+	XXXXX-----	+	+		+	2 102104. SHOP ASSEMBLY	500.
+	XXXXX----	+	+		+	2 102103. SHOP ASSEMBLY	500.
+	XXXXX--	+	+		+	2 102102. SHOP ASSEMBLY	500.
+	XXXXXXXX-----		+		+	3 103104. UNIT OUTFIT	650.
+	XXXXXXXX---		+		+	3 103103. UNIT OUTFIT	650.
+	XXXXXXXX-+		+		+	3 103102. UNIT OUTFIT	650.
+	XXXXXXXX	+	+		+	3 103101. UNIT OUTFIT	650.
+	+	XXXXXXXX-----			+	3 103108. UNIT OUTFIT	650.
+	+	XXXXXXXX-----			+	3 103107. UNIT OUTFIT	650.
+	+	XXXXXXXX----	+		+	3 103106. UNIT OUTFIT	650.
+	+	XXXXXXXX--	+		+	3 103105. UNIT OUTFIT	650.
+	+		XXXXXXXX----		+	3 103110. UNIT OUTFIT	650.
+	+		XXXXXXXX---		+	3 103109. UNIT OUTFIT	650.
+	-----+	-----+	-----+	-----+	+		
	JAN 81	FEB 81	MAR 81	APR 81			

The limiting resource problem, however", is not without its own limitations. There is a point beyond which resources are so scarce that the project cannot be expedited within the time-frame planned. In terms of the *critical* path method, this means that a point is reached where there is no more slack time available for delaying activities in order to avoid those time periods of full resource utilization. The only recourse, under these conditions, is to accept the resource excesses by scheduling over-time, additional sub-contracting, and/or new hires.. etc...or allow the entire project to slip. Figure 4.1.3 illustrates the problem where no more slack can be bled out. of the network schedules,

Any given work package may exhibit multiple resource limit restrictions. The planning process must accommodate at least for the worst case; i.e., the resource with the greatest excess over its limit,

## 5.0 The Updating Problem

While good planning in the beginning of a project is a good step toward insuring the successful completion of the project, circumstances do arise that cannot be anticipated beforehand and can alter the course of the project costs and/or schedule. It is unlikely that the actual duration of an activity will equal the estimated time shown in the original analysis. The initial plan can help get the job organized and started right, but as activities take more or less time than originally estimated, control of the work is lost unless the plan is updated to monitor progress, evaluate impact of deviations, and to adjust planning in order to complete the work by established contract requirements,

An "out-of-control" project can be recovered by means of strategies developed by a plan control team and a meaningful performance feedback system. However, the longer the delay to respond to problems, the less the chances for a successful recovery. Management needs a capability to constantly view status and determine just how bad the problems are and what areas should be given the highest priority to minimize costs and delays. Figure 6.0.1 illustrates a classical need for re-planning. The "bow wave" phenomenon is not unusual when plans fall apart: schedules not being maintained and the progressive growth of remaining work piling up as time advances.

Recovery strategies must not only minimize problems that inevitably arise but also should try to improve upon costs and schedules from planned levels. These efforts, however, should not ignore the effects of limited resources upon solving the problems.



TOTAL MEN PLANNED

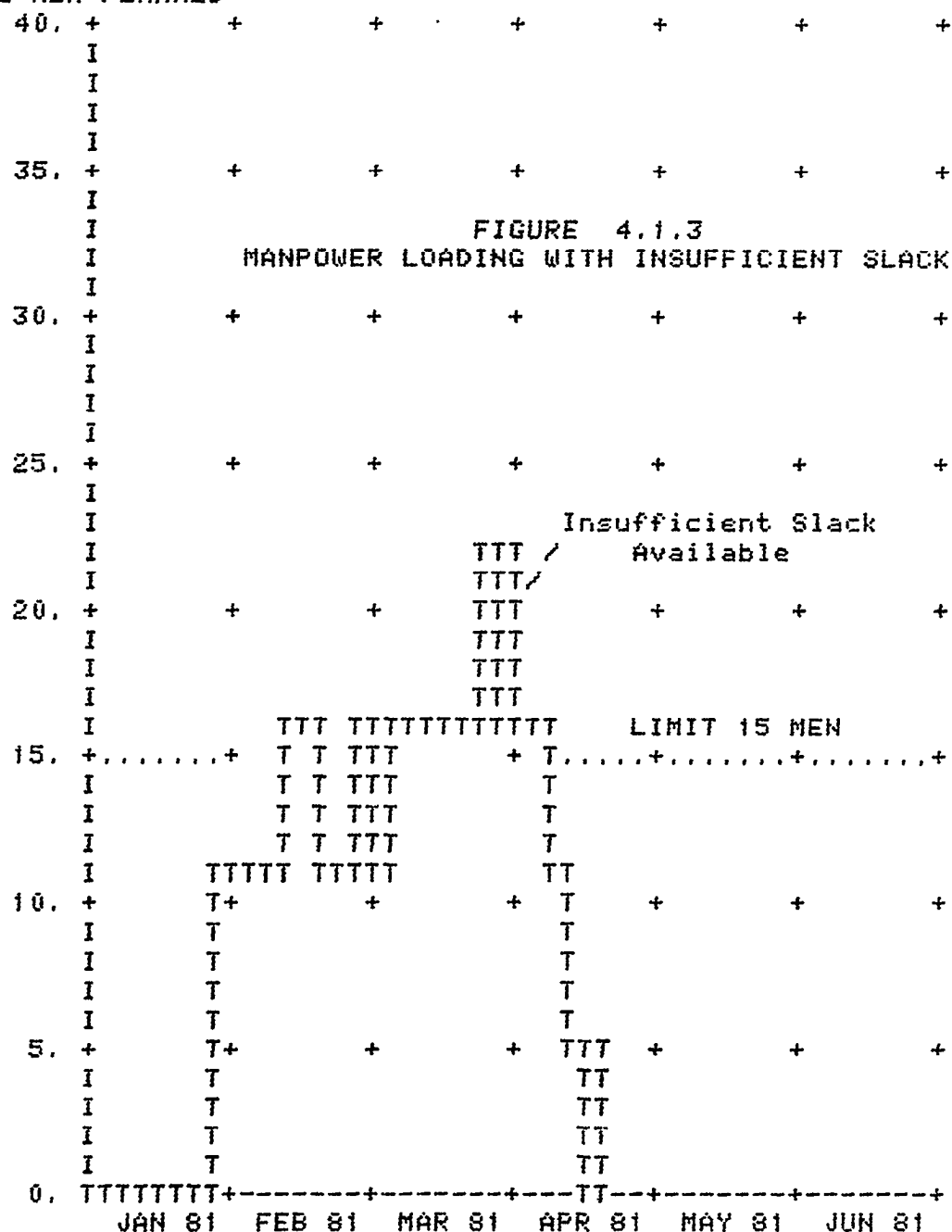
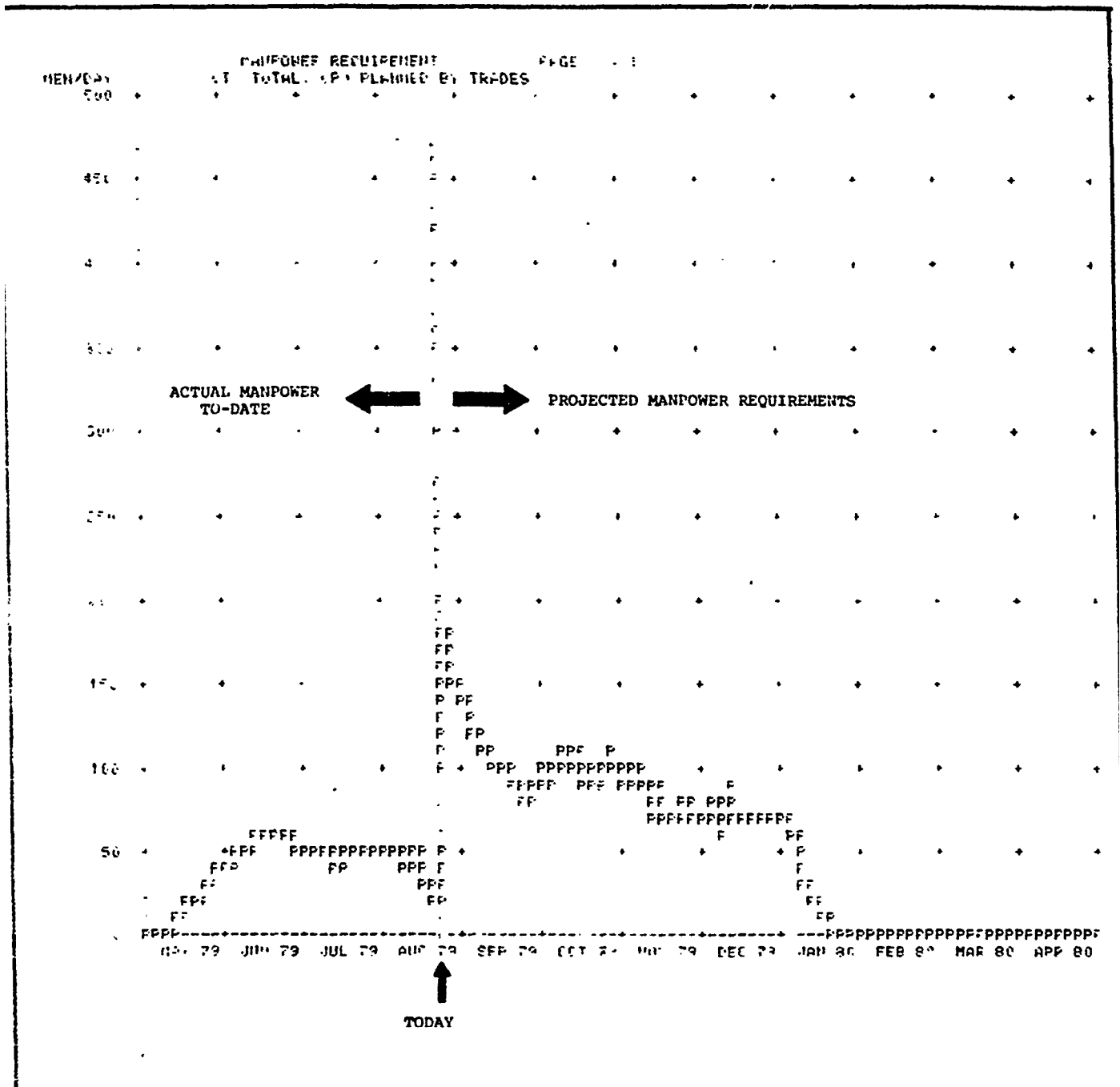


FIGURE 5, 0.1: Classic Example OF Need To RE-Plan



## 6.0 Conclusions

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The effort to plan and schedule large-scale ship production operations cannot be done effectively by manual means, especially for those yards who keep planning staffs to a minimum. The scope of variables that should be considered are too many and the work required to assemble all necessary information needed to develop realistic production schedules and determine economical resource requirements too overwhelming.

Solutions to this problem can only lie with computer software systems, provided they adequately address the practical aspects of planning: a system that is reasonably straightforward and uncomplicated, yet provides a reasonably accurate modeling of the work to be performed. The system must also be capable of producing a complete set of production plans without undue delay; shipbuilding typically operates on too short a fuse to permit a lengthy planning period prior to the on-set of production.

SPAR Associates, Inc. has developed various computer software systems that have been designed to meet these needs and more) they employ techniques that enhance the planning and production control processes even further than systems available in other industries long engaged in automated planning methods. The shipbuilding problem is one that offers special challenges particularly with regard to developing schedules that meet contract obligations within the constraints of the shipyard's limited available resources.

IMPLEMENTATION OF A PRACTICAL PLANNING AND PRODUCTION CONTROL SYSTEM  
IN SMALL AND MEDIUM SIZED SHIPYARDS

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ABSTRACT

Small and medium sized shipyards (200 to 1000 employees), particularly those growing rapidly from hands-on control by a few managers to a size requiring delegation of authority to superintendents and foremen, find that they have all the management control problems of the major shipbuilders but without the staff and administrative resources to easily cope with them.

Typically we find the small shipyard operating at best with a schedule covering a few key events, no integration of engineering output with production needs, an accounting system which accepts cost charging to few accounts but without budgets or work packages to control scope, schedule and manning, drawings without bills of material and every supervisor in the company participating as a material expeditor.

Although the depth of detail required in a small shipyard planning and production control system will vary with product complexity, personnel strengths, and contract construction period, the basic elements of a sound system are markedly similar and cannot be ignored without incurring loss of performance, deterioration of productivity and schedule delay.

## INTRODUCTION

In our visits to small and medium (even larger) shipyards, the difficulties and key to practical planning production control might be compared to the story about the telephone superintendent who sent two crews out one morning to set poles along the highway. Late in the afternoon when he checked out the days progress, he found one crew had set 27 poles and he complimented the foreman on his progress. His, perhaps unfounded, pleasure continued until he questioned his other foreman and discovered that crew had only set six. While being berated for his performance, the foreman defended his work by advising that his crew could have set as many as the first crew if they also left 30' of poles sticking out of the ground. In a slightly more apocryphal and ethnic version of the same story, the low productivity is justified by the foreman's difficulty in overcoming the six Polish crew members complaints about being set in the holes, upside down.

In either version, or a combination of stories, you can find some of the production control problems that face all shipbuilders. Questions quickly come to mind;

- Did the crews have a drawing or a work instruction to tell them what was to be done? and How?
- Did they have a schedule and a budget to tell them how many poles they were expected to set each day?
- And if we can laugh and not cry at the possible misinterpretation between wooden and human poles, we can ask where was the bill of material?

Now all of this, is a gross oversimplification of production control but how much more prone are we as shipbuilders to repeat this type of performance when attempting to construct one of the most complicated products known to man under the typically erratic contracting and delivery conditions imposed by our competitive market.

Much has been written in the last few years concerning production and inventory control theory and practice, and some small segment of these writings are applied to shipbuilding. They describe the glories of network planning in all its forms, computerized integration of engineering, materials and the production process, MRP, computer aided design, and on ad infinitum. If you research these writings very carefully and apply your best inductive logic to the hints between the lines, a few glaring realities become apparent.

Most, if not all, of the production theories have been created, or modified from, theories developed, in large mass production companies with large experienced staffs of engineers and systems people. Most of the production control systems published concerning shipbuilding have been based on experience in large ocean going shipyards and yet even with these sophisticated systems, profitability in the major yards has not been encouraging. But of more importance, the successful systems demand that a basic minimum set of prerequisites and conditions be in place in the yard before these highly touted systems can be implemented and before meaningful performance measurement can be expected.

What is surprising to us as consultants as we go about trying to improve our medium sized clients capacity, productivity or profitability is the infrequency that these basic prerequisites are in use and the further rarity of any reliable measure of the yards capacity to use as a baseline for future performance measurement even when strong productivity improvement programs are being attempted.

Perhaps to put this situation into context, I can describe an atypical small shipyard which is attempting to grow into a medium size yard. It was probably created by an eager entrepreneur with a few loyal and energetic friends who could purchase the materials and construct a simple boat or ship without going bankrupt. We find a yard superintendent with some experience as a crew boss at a steel fabricators or at the waterfront doing voyage repairs, a storekeeper or buyer learning to become a materials manager, a timekeeper or production clerk attempting to plan and control ship production, and all the staff trying to become estimators and financial managers. The yard manages its personnel and manufacturing via hands-on daily control by the several senior officers but is growing "like Topsey" and usually has not developed those systems or skills of delegation required to make sense of the larger company it is becoming. In-depth in-house engineering is a dream and most often is a service purchased from a design agent who contributes little to the yard's internal disciplines. Oh, you of the major yards and the shipbuilders councils may ask; Can this be? Can they survive? The rather pragmatic answer is, that some of those yards which survive, by dint of very hard work and rather frantic juggling of day-to-day problems, seem to make quite generous profits, but expansion comes very hard.

So what are those conditions that large yards and companies depend on as a foundation for good planning and production control but which seldom are adequately developed in the smaller yards. If they are available in your own yard, you are blessed and should be complimented, and probably don't need this paper.

The minimum conditons to produce good performance, production control and accountability of cost, labor and material, not just in construction but also in engineering materials and preparation of work packages, are:

- a) 'A schedule for construction drawing issue integrated with the production schedule.
- b) An accurate and comprehensive bill of material for each drawing and accurate list of owner furnished material.
- c) A schedule delineating both production's requirement for receipt in yard and necessary ordering dates to meet the production work start date.
- d) Engineering acceptance of responsibility to requisition all material for the ship.
- e) A dependent sequence construction schedule tied back through prerequisite shop manufacture, material procurement and engineering activities to contract award.
- f) Published, well scoped, work packages which describe jobs which are to be accomplished by one trade, at one location and in one relatively continuous span time.
- g) Material accountability by work package.
- h) Labor cost assigned to work packages and accumulated against a moderately detailed cost account system.
- i) A cost account system which simply summarizes labor costs in most frequently encountered production packages.
- j) A construction estimate fragmented into the cost account units.

At this point, I'm sure, some listeners will confidently assure themselves of a place in the shipyard hall of fame with an "of course, what else?" and more will react rather defensively that their peculiar market place never allows enough time between sale and construction for all that bureaucracy, folderol, etc.. I can suggest that without some of the items, if your ships are delivered on time and for a profit, it's probably due more to good luck than good management. With others, even if you don't think they are being done, they really are, but more expensively and by the wrong departments.

## MANAGEMENT'S ROLE IN PLANNING

Planning is one of the most powerful tools in each manager's bag of tricks. Each functional manager must be responsible to plan his own department's output in a manner that supports the shipyard's efforts to meet its contractual commitments. It is all too easy for managers to avoid departmental planning and merely react to events as they occur. Thus the late signing of a contract automatically justifies engineering and material delays and delayed engineering excuses a late ship delivery. Obviously management cannot also automatically accept the inevitability of these impacts on contractual delivery commitments. Therefore, we want to encourage a strong commitment to planning by all senior shipyard managers with a dedication to self-initiated recovery plans to offset any prerequisite delays they suffer. Nevertheless, because unenlightened self-interest or self-sympathy sometimes overwhelms enlightened attempts to keep the program on the track, it is also desirable to have a planning and production control function independent of line managers' organizations to promote objectivity and pragmatism in analysis of the shipyard's performance. In a small shipyard it is highly desirable that this group report to the chief operating officer of the company. The function can be placed under a line department in the yard's organization but always with the risk that the planning group's objectivity will become compromised when their line department's delinquent performance begins to directly impact the shipyard's ability to deliver ships. It can be even more devastating if the planning group is used as a vehicle to misdirect blame for shipyard delays.

Although it has been easy for the industry to acknowledge the reported benefits that have occurred from the pre-planning and production engineering in major ocean-going complex ship programs it is a quantum leap to accept and implement the same techniques in simpler ships where no qualified staff exists in any depth in the yard. But without some attention to early strategic planning and institution of formal management control of the work, schedule and budgets, then the small shipyard is just as vulnerable to the stumbling and fumbling and delays and even less well staffed to manage a recovery.

Planning and production control is not a luxury, it is an absolute necessity.

For effective control of production, management must apply a different viewpoint at each level from foreman, to superintendent, to production manager, through Vice President of Operations and on to President, or whatever echelons are in place. Not only must the viewpoint change,



but the form and content of analytical and progress reports are different at each level. For instance, the quality of production control is not enhanced if a foreman's work order delinquencies are merely reviewed at successively higher management levels with increasing frustration and fury and with decreasing knowledge of the facts and conditons creating the delinquencies. We can clarify this by a brief look at the span of control appropriate to each level.

The FOREMAN is principally concerned with accomplishing a weeks worth of work orders every week by assigning men on his gang skillfully and sequencing assembly operations for minimum cost and shortest time. He works to a list of work orders in sequence of scheduled start dates. He has a planning responsibility to look ahead a few days to avoid downstream interferences with another craft and to offset a delay in one area with an acceleration elsewhere. The foreman must be encouraged to report cost and schedule performance accurately even when performance is less than favorable. We must always remember that the first line foreman job is not principally to meet contract milestones nor to chase material but rather to secure employee performance and complete individual work orders within budget and schedule.

The SUPERINTENDENT, unlike the foreman, has a primary responsibility for a geographic area, be it a shop, a ship, a platen and the efficient application of several foremen to avoid conflicts in the use of people, space and equipment. The superintendent must use an area list of work orders sequenced by scheduled start date, to constantly drive to start work on or ahead of schedule and secure first class assistance from Production Control to confirm that scheduled jobs are workable with drawings and material available. He is principally responsible to document the realities of significant schedule and budget variances and report them to Production Control to improve the quality of future estimates and schedules and to differentiate between poor performance and incorrect budgets and schedules.

The PRODUCTION MANAGER'S efforts must be directed toward balancing manpower and resources to achieve completion of specific ships on schedule. It must be recognized that, although he is usually held accountable for poor cost performance, his principal influence on costs is achieved by insuring a clear perspective of priorities between areas and contracts and by creating an efficient workplace. He can periodically analyze those cases of poorest work order schedule and cost performance to remove the causes for the poor performance. One of the Production Manager's most useful tools in a work order list for each contract in sequence by scheduled start date, with-which he can anticipate

delays due to missing drawings and material and identify jobs which can't be started due to personnel or facilities shortages. The Production Manager and Planning and Production Control Manager together represent a team which must constantly scheme to recover delays and complete prerequisite activities so that the Superintendents are in a position to exploit good performance elsewhere. You must be ready to smile when you get kicked in the pants by success.

Finally the VICE PRESIDENT OF OPERATIONS and the Chief Operating Officer are principally concerned with insuring that production receives timely support from engineering, materials and production control and with balancing workloads in a multi-plant operation. Further they must maintain a very clear perspective of the manpower required to meet the demands of all ships under construction. All too often, wishful thinking concerning anticipated productivity improvements, possible reductions in absenteeism, inflated predictions of success in hiring programs, and sheer self delusion, that undermanning can improve budget performance, are substituted for man load forecasting based on realistic current performance. Once top management allows the yard to continue undermanned until a significant percentage of all work orders are no longer accomplished close to schedule, it becomes virtually impossible for lower levels of production supervision to manage the complex priorities required for recovery. Serious work assignment errors start to occur. Rarely, if ever, can shipyard performance be improved by forcing the foreman to underman jobs in hope of reducing costs while allowing schedules to slip. A foreman can be expected to manage the assignment of working jobs on schedule to the limit of assigning his available crews correctly. He cannot consistently handle the multiple problems of undermanning jobs, no meaningful schedule and an unclear demand to improve productivity. In these terms productivity is a symptom of good planning, sound budgets and schedules and correct manning. It is not a function assignable to line foremen.

### WORK ORDERING

In most modern manufacturing companies and in many shipyards, some form of job order, shop order, manufacturing order or work order, is issued to the production department to direct the accomplishment of tasks on a contract. Frequently only a small portion of all the direct charging work is covered by work order while the balance is merely charged to a few standard cost accounts. Some shipyards only use a cost account list and we have worked with yards which use as few as three cost accounts for a complete ship and with each account valued at more than 20,000 manhours! Patently this approach only provides a vehicle for cost accumulation but offers neither useable work scope direction to the foreman nor any hope of schedule or cost control

by management via the work ordering system. To be useful and helpful at the foreman level, a work order must provide a manageable work scope, a schedule and cost envelope which compliments and defines how and when the content of a drawing and its bill of material is to be incorporated into the ship. After reviewing the work ordering process in many shipyards, we have concluded that, regardless of format, an adequate work order needs certain features which should be developed in a planning or production control department. If these features are not provided in the work order then ultimately they must be researched and produced by other groups, with poorer records, with less lead time before construction starts, and almost always at greater cost and confusion. If a ship is to be built at all, then before it is completed, someone (and if no one else, then the foreman, fitter or mechanic) will determine which jobs are to be done, in what sequence, where, when and with which drawing, materials and manpower. Unfortunately, the more this burden falls on the foreman, the better the chance for last minute delays due to late or missing drawings or materials and for conflicts between trades to develop. Even more damaging is the removal of the foreman from his primary function of crew assignment, on-the-job instruction, operations sequencing and cooperation with other foremen working in the same area. Although a foreman should never be completely relieved of his responsibility to plan his own jobs, it should be obvious that administrative planning can be done cheaper and at a much earlier date in the contract by professional planners working directly with Engineering and Materials groups to prepare well scoped work orders. Figure 1 lists the minimum information required in a comprehensive work order,

The time span and maximum budget for a "good" work order has always been a topic for lively discussion in production control groups. Again, there does not seem to be a "magic number" for either cost or time, but experience dictates that the order should be comprehensive and manageable by a single foreman and the work should be accomplished in a relatively unbroken time span. When tasks start to exceed one thousand manhours or a couple of weeks span, planners and superintendents should restudy the job to try to uncover a logical split which will also feel comfortable to the foreman. Work orders which are larger or longer than the 1,000 hour/two week size tend to get out of control before the typical work order reporting of "start", "complete" and "hours expended" reflect a problem. When the work order reporting system does not provide control, then it's back to eyeball progressing, guesstimates, little black books and all the other alternative controls that have been used for centuries. Thus the correct size of a work order will give the foreman a meaningful job to do and will give management cost and schedule control.

## SCHEDULES

It is not surprising that most shipyard managements would probably agree that schedules are a necessary element to pace the work on a shipbuilding contract. What is surprising is the infrequency of integration of engineering, procurement and production schedules into a program of what must be done to meet contract delivery. What is even more surprising is the infrequency that the schedules are used as a working decision making tool to keep the construction on track. For example, we find assiduous use of milestone schedules unsupported by either a tautly constructed dependent sequence between construction requirements and their engineering procurement prerequisites' or a resource analysis to confirm that manpower and facilities support the milestones. With this dilemma, meeting or missing milestones provides no real evidence of progress toward contract completion. When a milestone event is achieved, what guarantees does management have that all work planned to be complete by the event date is actually complete? Or do we have a successful milestone surrounded by an incomplete ship?

There are a variety of scheduling tools in the planning/production control kit whose content and degree of detail can be tailored to satisfy the full range of shipbuilding programs from simple barges and work boats to complex ocean going Naval warfare vessels. Table A describes this collection of schedules. \*Once a shipyard becomes involved in construction of more than one ship at a time some of these schedules are mandatory to provide control of resources, ship-to-ship sequencing, optimum ship construction approach, priorities for work orders at each work station, and to integrate engineering and procurement support of production. Briefly these are:

- a. Master Construction Schedule defines major key events on each ship and usually reflects usage of the ship ways and final erection areas. Usually developed for each additional ship contracted for from historical data on similar ships, and then refined as detailed construction scheduling is completed. Since this schedule represents the principal strategic plans of the company, it is not revised without top management approval. All subsidiary schedules should be complimentary to it.

'\*Note: The timing and distribution are variable with the product mix and frequency of delivery.

- b. Ship Construction Schedule defines the dependent sequence of fabrication, assembly, erection and systems installation for each ship. This provides a baseline for detailed work order scheduling. Until a shipyard can hire or train experienced ship planners, this schedule must be created using the best available shipbuilding talent in the yard; usually construction superintendent, production manager, et al.
- c. Work Order Master Schedule is initially a forecast of all work orders required for a ship and then is refined as drawings become available. This schedule paces, not only all production work but also paces work order release and is the baseline for detailed drawing and material schedules.
- d. Drawing Schedule starts with a forecast of all drawings required to define the ship so that production planning can tell engineering when each drawing is required to support its respective work orders. Since many long lead material items cannot be procured until they have been defined on a drawing it may become necessary to schedule drawing completion to earlier dates to support material ordering. Engineering assumes this added responsibility.
- e. Material Schedules start with a forecast by engineering of principal material categories and long lead specialties which planning can schedule to show production material required in yard dates. Procurement can back off ordering lead times to create a schedule for Engineering material requisitions. This document paces both material ordering and delivery and should be integrated with the work order master schedule.

The approach used in the foregoing schedules is to create a forecast early in the contract to pace the program and then refine detailed line items as the design is developed.

Depending on the complexity of the product, the complexity of shipyard layout, and the difficulty of managing specific work stations, a wide variety of area and assembly schedules can be created to pace and sequence the work priorities. In general the effort should be directed toward use of the work order schedules tabulated by area (work center) to achieve necessary control. However, in troubled areas, it may become necessary to schedule in more detail (below work order level).

It should be noted that the foregoing discussion applies to the typical small or medium sized shipyard that is involved in a mix of customers, a variety of ships and low volume production runs. For large production runs of identical vessels, techniques more akin to MRP techniques are preferred.

Thus far we have not considered the use of automated data processing ADP techniques in ship planning not because of any aversion to its use, but more to highlight the absolute necessity to develop certain basic data and planning disciplines whether manual or automated systems are used. If any thing, the data base disciplines are more demanding than for manual systems and until each department can develop the data, the organization, the discipline and the personnel to implement such a program, ADP in the small yard is just one more confusion factor in Production management..

#### MANPOWER PLANNING AND PROGRESSING

Any shipyard, in fact any business, is concerned about cost and labor performance. The merit of this desire is obvious but the measure requires a baseline against which we can compare performance.

Although a formal work order system can provide such a baseline, any other task breakdown, which can be scheduled and have manload assigned to each day or week, will also be useful as a manpower and schedule baseline for performance measurement. The key to this performance measurement is the establishment of a planned manload against the calendar which consists of discrete and defined work packages. As long as we can assign manpower to each weekly increment of each task, we can plan our manloading. Subsequently we can measure performance in two ways:

- a) by comparing actual manpower usage vs planned usage, and
- b) by estimating whether we have earned an hour's worth of production for each hour expended.

For the statisticians among us, these are not dependent variables.

We can expend hours without earning progress -- this is the "wheel spinning syndrome" and occasionally we can progress without excessive manhour expenditure -- which might be called the "sometimes we get lucky syndrome",

but more accurately, we find that management is not always in control of the factors which produce progress.

In simplest terms we need to assign men or manhours to each task for each time period and accumulate these hours each week of the plan. First we measure actual manning expended each week and compare short fall or over-manning to the baseline each week. Separately we must determine whether we have achieved a day's progress for each job and guesstimating % progress achieved. In theory this approach appears sound; in practice, consistency and repeatability are doubtful since little effort is expended in training foremen as estimators and planners. Better progressing methods are available but they depend on precise work packages, short span times and task budgets developed by knowledgeable planners from sound historical data.

In any event, the benefit derived from applying manpower to each ship under construction in accordance with a forecast manpower plan is considerable compared to assigning manpower to whichever foreman or superintendent cries the loudest or, has maximum "clout" with the production management or conversely to routinely apply maximum manpower to the earliest ship to deliver regardless of impact on other programs.

Figure 2 is a simple version of a manpower forecast with weekly actual usage and variance recorded. The sample is for two ships but comparable tables may be created for individual trades or a collection of trades or ship programs.

## CONCLUSION

So what is the ubiquitous "bottom line" for a workable PPC system in the small shipyard? In summary we need:

An independent planning and production control group working with and reporting to the Chief Operating Officer..

A master strategic plan and an integration of schedules for construction, engineering and procurement very early in each contract.

Creation of small budget, short span work orders manageable by a foreman.

Clarification of production managements role at each level -

- work orders at the foreman level
- area control by Superintendents
- ship completion for the Production Manager
- multi-plant integration by VP of Operations

Manload forecasting and progressing summarized from work order budgets and schedules.

Material requirements correlated to individual work orders and based on an accurate bill of material from Engineering.

A dedication by line Managers of each functional group to progress their departmental efforts to the integrated schedules, and notify follow on departments of pending delays before they happen.

As we frequently tell clients production managers, "our job is to provide you with a PPC system that will turn you into heroes". To which one Manager responded, "I hope not posthumously? So do we!



### Brief Work Order Criteria

Size of Job	One continuous operation (preferably 40-400 manhours).
Span Time	Continuous operation (usually less than 2 - 4 weeks).
Supervision	One foreman.
Sequence	Uninterrupted by another work order.
Location	One work station.
Material	Finite collection of:  Piece marks or, Assemblies, or Work orders, or Combination of above
Cost	One cost code (charge number).
Budget	For each department/craft.
Schedule	For issue, required material availability, production start and complete.
Routing	Source of parts to be used and feed (delivery for next operation or in-process storage).
Special Equipment	Tools, jigs, fixtures, templates unique to the work order.
Scope	Minimum narrative to describe task and provide instructions on technical or sequence conditions.
Issue Data	Name of work order initiator and actual date of issue (that is - the date of release to Production with drawings and material available).
Work Order Number	A unique number for each work order, consisting of: Contract, Unit (Hull), Cost Code (item/sub-item), Serial and Revision.

Figure 1

MANLOAD PLAN

	TO	7/1	7/8	7/15	7/22	7/29	8/5	8/12	8/19	8/26	9/2	After 9/2
	DATE											
<u>SHIP "A"</u>												
Planned mh/wk		2000	2100	2500	3000	3500	3500	2500	2000	1000	1000	2785
Actual mh/wk	4000	1800	2000	2300	3100	3800	3900					
Over/under (-)		-200	-100	-200	100	300	400					
Cumulative +/-	-300	-500	-600	-800	-700	-400	-0-					
 <u>SHIP "B"</u>												
Planned mh/wk		-0-	400	600	1000	2000	2200	2600	3100	3600	3500	7000
Actual mh/wk	1000	300	600	600	800	1500	2200					
over/under (-)		300	200	-0-	-200	-500	-0-					
cumulative +/-	-0-	300	500	500	-300	-200	-200					
 <u>All Programs</u>												
Planned		2000	2500	3100	4000	5500	5700	5100	5100	4600	4500	9785
Actual		2100	2600	2900	3900	5300	6100					
over/under (-)		100	100	-200	-100	-200	400					
cumulative	-300	-200	-100	-300	-400	-600	-200					

Figure 2.

TABLE A

<u>REPORT OR SCHEDULE</u>	<u>FORMAT AND FREQUENCY</u>	<u>WHO USES AND WHY</u>	<u>HOW REPORT/SCHEDULE IS USED</u>
<b>MASTER CONSTRUCTION SCHEDULE</b>  Identifies all contracts in yard and for each contract shows key event schedules for delivery, launch, transfer, start construction, drawing completion and steel order and delivery	Bar chart. Monthly or when new contract is announced	Officers and managers. and planning. Monitor completion of major key events. Plan resources to avoid facilities conflicts	Executive staff, Production Manager and Production Control Manager should review at least bi-weekly and each division head should be prepared to report on ability to meet key events he is responsible for and secure agreement on corrective actions he will take to recover delinquencies.
<b>WORK ORDER MASTER SCHEDULE</b>  Identifies (and forecasts) all productive work required on a firm contract and includes schedule dates for W.O. issue, work start and complete with area where work is to be performed and budget. Schedule has ability to be maintained with actual dates and manhour cost.	ADP tab run Monthly by job in W.O. number sequence  ADP run Biweekly by area in schedule start sequence for incomplete work to date and two weeks in future  ADP run. Biweekly by job in schedule start sequence for incomplete work to date and two weeks (or perhaps four) in future	Planning Basic contract work control schedule  Superintendents and foremen and planner. Area control schedule and delinquency analysis  Production Manager Production Control Manager Contract control delinquency analysis	Planning uses WOM to insure that all work required on the contract is identified, sequenced, budgeted and scheduled.  Basic control tool to identify which jobs in priority sequence should be manned and worked first. Markup progress and problems by foreman to review with superintendent in weekly delinquency meeting. Superintendent uses to solve area holdups and manning and can be used for backup answers in weekly Superintendent progress meeting with Production Manager  Basic control and analysis tool to quickly identify contracts with large W.O. delinquency and take corrective action.
<p>Note: All tab runs from the work order master should include all columns in the "Job Status Summary" and the area run has to add a column for "Job Number"</p> <p>Work order masters are not revised to correct for production delays or poor performance. They will only be revised to correct erroneous planning, reflect major contract changes, or Master Construction Schedule policy changes.</p>			

REPORT OR SCHEDULE	FORMAT FREQUENCY	WHO USES AND WHY	HOW REPORT/SCHEDULE IS USED
<b>AREA SCHEDULES</b>  Area schedules are developed for several different purposes but initially are for planning to insure that ship erection, assembly and fabrication heel and toe sequences and span times are correct. Secondly they become a planning tool to analyze the various areas of the shipyard to insure correct manloading and avoid capacity overloads. After comprehensive contract work order schedules have been developed, the area schedule in either tabular or graphic form can be used as a control tool for an area foreman particularly in heavily loaded areas.	Bar chart or W.O. tab run in schedule sequence Biweekly Typical area schedules are:  Angle shear Flame plane N/C burn Plate shear Press break Plate bender Panel line Assembly slab(s) Erection jig Module assembly	Planner, to work out area sequence and span time and manload or machine capacity. Foreman as an area control tool. Planner to develop area recovery schedule on a one shot basis	Planner develops an area sequence schedule as a tool to assist in the refinement of work order master schedules and to interrelate the schedules for several contracts work in the same area of the yard. As work on a contract proceeds, special area schedules may be developed to help highlight and analyze overloads and delinquency situations on a one shot basis. Planning should not attempt to continuously revise these in lieu of the work order master nor should a recovery schedule replace the Job Status runs as the control for each job.
NOTE: If area schedule development and analysis demonstrates that major key events must be rescheduled this may be done with approval of the Vice President - Operations, however delivery schedule will only be changed with approval of the President			
<b>MATERIAL SCHEDULE</b>  Identifies by category of material (and specific equipment components) when requisitions must be given to Procurement, when purchase orders must be placed and when material must be received in yard and provides actual dates of accomplishment and purchase order numbers. When appropriate, schedule should also define when vendor technical information and release for manufacture is required.	Biweekly. by contract Tabular list Typical categories:  Steel plate Structural shapes Castings Forgings Hull fittings Pipe Valves/fittings Machinery components Electrical controls Coatings	Materials Manager as basic control document to insure material order and delivery Planning to integrate material delivery in support of work order start schedules. Engineering to control purchase requisition preparation.	Materials Manager should make review and expedite Engineering for any requisitions not received to schedule. Once order is placed, Materials should advise Production Control continuously of any delivery promises which do not support required delivery schedule via a markup of the material schedule. Planning and Production Manager use markup report to develop work around and recovery plans to offset delinquent deliveries. Engineering should analyze the purchase requisition schedule and insure that order information is prepared to support even though drawing development is not complete or scheduled to the same date.
NOTE: Materials Manager should develop standard lead times for each category of material and for conversion of purchase requisitions into purchase orders so that Planning can schedule the material list not only for delivery but for material requisition and purchase order placement.			
Material Manager should expedite Engineering to provide material requisitions to support his required ordering schedule, expedite and negotiate with vendors to secure not only material delivery but vendor information to schedule, and must advise Planning and Production management when ordering, information and delivery dates are not being met.			

REPORT OR SCHEDULE	FORMAT FREQUENCY	WHO USES AND WHY	HOW REPORT/SCHEDULE IS USED
<b>MANLOAD PROJECTION</b>  Distributes work order budgets in equal weekly increments across the work order schedule span time and summarizes the total budgeted manhours weekly either by contract or area.	Tab run. Monthly by contract for all work orders scheduled to be started and not complete as of the report date together with total manhours for all contracts by week and for each contract. Summarize backlog manhours.  Monthly by area similar to the "by contract" run.	Production management to determine manning requirements for each contract and overall yard  Superintendents to use to analyze forthcoming work center overloads and revise area manning	Basic planning tool for Production management to predict and act on manpower implications for planned contracts.  Note: By inserting "dummy" work order masters in the file for potential business, similar projections can be made to analyze impact on the workforce.  Planning and Superintendents can determine work center (area) manning or machine overload or excess manning and prepare manning reassignments or farmout and multi-shift corrective actions.
<b>STATISTICAL WORK ORDER REPORT</b>  The report is a statistical count by contract and a total of all contracts to reflect both total number of work orders in the file and delinquencies against schedule for work order issue, work start and complete.	ADP tab run. Weekly (when total delinquencies are low change to bi-weekly) by contract and counting number of work orders in the file and number scheduled, actual and delinquent as the report date  Graph by contract and one for total contracts weekly plot  ADP tab run Biweekly by area with same counts as by contract	Production and Planning management to determine quickly where recovery action is required  Planning prepares for Production management review  Superintendents to spot delinquent performance by area quickly. Planners use report the same way	Production management use as basis of selecting production agenda topics for the weekly meeting with the Superintendents.  Planning should analyze delinquencies by contract to select areas which require recovery scheduling or corrective manloading and make recommendations to the Production Manager and Production Control Manager  Planners and Superintendent review each report and select most delinquent areas for detailed work order analysis and development of corrective action recommendations

REPORT OR SCHEDULE	FORMAT FREQUENCY	WHO USES AND WHY	HOW REPORT/SCHEDULE IS USED
<p><b>LABOR PERFORMANCE:</b></p> <p>A measure of manhour productivity versus budget by either area or contract. There are a variety of calculations that maybe developed. One of the simpler is described here.</p>	<p>Tab run. Biweekly by area for all work orders closed out in previous quarter (13 weeks).</p>	<p>VP Operations, Production Manager, Production Control Manager, to identify areas of significant budget overrun or underrun.</p>	<p>A consistent budget overrun/underrun can indicate either poor production performance or erroneous budgets. Either situation requires analysis and correction at the work order/work site by Production Manager and Production Control Manager together with the cognizant Superintendent and Foreman. If budget is erroneous this should be corrected (certainly on the next similar job, and if it is significantly affecting progress measurement, then on the current jobs). If Production performance is poor then several actions are in order:</p> <ol style="list-style-type: none"> <li>Adjust area manning levels to be consistent with performance so that area is not over/undermanned.</li> <li>Determine whether work site facilities, tools and conditions need modification.</li> <li>Correct personnel assignments and training to produce costs below budget.</li> </ol>
	<p>Tab run. Biweekly by contract for all work orders closed out on the contract.</p>	<p>VP Operations, Production Control Manager to evaluate performance between similar ships within a contract and compare to similar ships on previous contracts.</p>	<p>If performance at comparable stage of contract completion is significantly poorer (or better) than previous similar ships, first confirm that cost charges to job are being correctly applied. Then if performance is poorer, do a detailed analysis and comparison of work orders to isolate the principal (area) contributors to the problem. Direct Production Manager to take corrective action with area Superintendent. If performance is better than expected learning curve (and repeatable on follow ships), adjust forecast man-load and manning assignments to avoid overmanned follow ships.</p>
<p><b>SHIP CONSTRUCTION SCHEDULE</b></p> <p>Identifies major area and system critical path schedules and controlling relationships between each area. Schedule is most useful on ships with more than a one month construction period.</p>	<p>CPM, ADM, PDM, Bar chart or key event chart updated monthly with actual dates</p>	<p>Officers, Production and Production Control Managers Superintendents to secure visibility into ship schedule and progress activity</p>	<p>This schedule is a high visibility document which quickly shows the next major event to be accomplished in each area and gives an insight into the significant controlling paths from contract award to delivery so that the impact of event delays may be analyzed and corrected.</p>
<p><b>NETWORK &amp; STACKING SEQUENCE SCHED.</b></p> <p>Basic planning tool to develop dependent sequence scheduling of all significant contract activities commencing with contract award and including engineering, material procurement, fabrication, assembly, outfit, test, trials and delivery.</p>	<p>CPM, ADM, PDM, PERT etc. (that is, any form comfortable to and within the competency of the planner and Planning Manager, which describes both dependent sequence and span times. Frequency may be one time as a base for work order scheduling or periodically to analyze delay impact and resources</p>	<p>Planning. To insure accurate work order, material and engineering scheduling and to analyze manpower and facilities usage.</p>	<p>From historical data a dependent sequence of activities is prepared for ship construction and all prerequisite activities leading to and supporting ship construction (engineering, procurement, work ordering, ship construction). Each activity may be described in terms of work scope, span time, manning and perhaps cost and facilities usage. The network then provides the basic schedule framework for these activities and the detailed schedules for their performance and also acts as a vehicle for future analysis of program delay to the most critical (shortest) paths to delivery.</p>

**A PRACTICAL APPROACH  
TO USING STANDARD SOFTWARE PACKAGES IN SMALL SHIPYARDS**

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**ABSTRACT**

In the growth of a shipbuilding concern, a time arrives when manual efforts to control cost and report status become undesirable. However, when an attempt is made to apply readily available software, many obstacles are presented.

One approach to avoid many of these obstacles is addressed. By describing vessel construction through a network of dated work orders, and the treating of this network as a structured bill of material, standard software packages can be used to manipulate the data necessary to provide material requirements planning and job cost accounting. Critical issues impacting the selection and successful implementation of computerized systems are also discussed.

## INTRODUCTION

In the growth of a small shipbuilding company, a time arrives when manual efforts to control costs and report status become ineffective. If the company is to continue to be successful it will need to produce more of its product at the same cost or the same amount of product at a lower cost. Besides improved facilities, better controls are needed on costs if these goals are to be attained. In the past small shipyards were able to see the need for controlling the cost of manhours much more visibly than the need to control the cost of their materials. However, in recent times the cost of money has directed more light on material and inventory control. Managing with huge piles of raw materials stacked in front of the labor can no longer be tolerated. The associated simple systems for stock piling needed materials do not represent an efficient way of supporting production.

Many companies attempted to eliminate their material control problems through buying all materials directly to the job. This solution was found ineffective since the shipbuilding business is based on signing contracts with minimum lead time, which is not compatible with direct purchasing from vendors with long lead times. Missed delivery schedules quickly impacted production manhours adversely.

Attention was then turned to managing inventories with tighter controls, increasing material planning efforts, and monitoring job progress more closely. The only way such controls could be obtained short term was to add personnel in the support functions of production and inventory control.



However, as departments grew, they became less effective, owing to duplication of effort and reduced overall professional ability as a result of available, but untrained personnel, being pressed into jobs they were not qualified to fill. The manual systems designed to control costs soon became subject to greater errors than before and confidence in their accuracy and effectiveness diminished rapidly.

The need for expanded use of the company computer became obvious to those who thought, "Our overhead will not continue to grow if we rely on better use of the computer". However, probably no one in the organization had any idea as to how best to tap this great resource. Usually the company had a computer on which it had been processing accounting, payroll, and personnel records, but little involvement in the control of its material and job progress.

#### SOFTWARE ALTERNATIVES

The question now becomes: "How to expand the computer's capabilities to solve the problem?" There are three alternatives: (1) develop software using in-house personnel, (2) pay a software design agent to develop new packages, or (3) purchase standard multi-function packages and modify them to suit local needs. The choice of which alternative to pursue is dependent on the extent the existing systems must be upgraded. If most of existing automated systems are satisfactory but one area needs improvement, then the choice falls between the first two alternatives. An in-house effort would be the least costly, but is slower compared to software design agents that are usually more expensive but will provide a quicker solution. However, this paper will address the need for extensive new systems and in that case

alternative #3 is the best choice.

The development of a comprehensive automated control system with integrated functional modules is an extremely complex task. Few in-house data processing departments have systems analysts and programmers who understand manufacturing control systems well enough to provide the detailed programming which would duplicate most of the significant functions of a comprehensive Manufacturing Resource Planning (MRP) software package. Even if the company had a few of these people, they would not be enough to carry out a total system development program. Immediate expansion by hiring new personnel is not the right answer. It is unlikely that the newcomers will understand the ship-building business and its unique characteristics, thus delaying progress while they become acclimated.

The argument against using a software design agent to develop MRP software packages for your specific needs is simple; why bother re-inventing when you can spend that time and resource modifying a system already designed for someone else? One advantage of working with a developed set of packages is that the functional inter-relationships are already debugged through efforts of previous installations. Another advantage is that the cost and time required in modifying an existing set of packages are significantly less than developing your system from scratch. Another disadvantage associated with the use of design agents is that your data processing personnel do not become knowledgeable in the detail workings of the packages. The vendor wants to continue providing upgrade service in the future rather than have you proceed on your own.

The use of ready made packages is not problem free. It is difficult to locate vendor software which meets the needs of a small shipbuilding company. Lack of in-house knowledge of what's available, due to minimal exposure to software state-of-art, is as much a part of this problem as the size of the software market represented by the low volume make-to-order shipbuilding companies. Most packages are tuned to high volume manufacturing or at least manufacturing in the environment of structured bills of material. The software salesmen do not understand the shipbuilding environment or how to relate their capabilities to the manufacturing needs. This situation is compounded since most shipbuilding people do not understand high volume manufacturing and its controls either.

It is important that the software vendor salesmen not be allowed to overpower the in-house systems people. To avoid this situation, production and inventory control personnel must undertake an educational upgrade program in classical theory and its application in the state-of-art software as well as in shipbuilding. This should be an on-going effort sponsored by top management. The idea is to stay up with improvements in the software and to be able to interpret their value for application to a shipbuilding environment.

During the review of available software systems it will become clear that most operate well only when a tightly structured bill of material exists where all parts have unique part numbers, and when those parts are scheduled individually. Highly structured bills of material are not present in most small shipbuilding companies. Without detailed levels of a bill of material with discreet part numbers it will be impossible to use standard MRP software. The use of phantom part numbers for sub-assembly

stages as part of the bill of material, which might be the proposed solution from a salesman, is a difficult concept to accept. Without this solution, vendors are at a loss to fit their packages to your system. What is needed then is a bill of materials for shipbuilding that defines the product structure without imposing additional complex concepts on the organization.

#### WORK ORDER SYSTEM

Most shipyards utilize work order systems which define portions of work for a given vessel or contract. These work order systems can be used as a structured bill of material if the work order itself is designed properly. The key characteristics of this type work order are: a charge number, a scope of work, a list of materials involved, the source of those materials, and the next work order to be fed. The work order identification number is the time charge number which describes the cost account and type of work to be done. It also identifies a particular work scope from a master listing of work scopes. The scope of work is a task description provided initially by production as a manageable amount of work. A complete library of such tasks can be written which would build all of the company's products. Essentially, these work scopes provide the production engineering breakdown of the contract drawings into manufacturing modules. The materials required to accomplish the task described by the work scope are listed along with their sources. These sources are either purchase order numbers, inventory part numbers, or other work order numbers. By also showing the next work order that the completed pieces feed, a linking of all work orders is accomplished. Therefore, a network of work orders is formed which can be treated as a structured bill of material having work order numbers acting as phantom sub-assembly part numbers. Since these numbers are used daily by production personnel for time

charging, their use in an MRP system will not be misunderstood or distrusted. By scheduling the work orders, a direct input can be made to an MRP package listing materials by their quantities and date required. Using the work order numbers as phantom parts allows the MRP logic to sum to the lowest level to determine raw material requirements. Since manhours are charged to work orders as well as materials, the capability to sum up materials and labor costs at each step of production will exist. Such a work order system then provides the link between present day MRP software and the shipbuilding manufacturing environment.

#### IMPLEMENTATION PLAN

Given this link, the question becomes "How best to proceed towards upgrading the manufacturing control system?" The best approach is to review the total operational logic of the company's functions with emphasis on information requirements of each function. As each function is analyzed in relation to how its existing design and operation fits into the total picture, problem areas will be highlighted. In many cases potential solutions to these problems will become apparent as one function is compared to another. Some problems will call for further analysis; and, priority for further effort will be established. The output of this review will be the purchase specification for vendor software and an implementation plan for upgrading the management information systems. In order to facilitate on-the-spot decision make during the review, a team of top management personnel should be assembled to carry out the analysis. This also insures a high level of project sponsorship, the single most important key to success of such an implementation plan. Finish the team project with a financial analysis of the costs and benefits of your implementation plan with emphasis on measureable benefits to provide justification for proceeding and controls for monitoring progress.

There is one other key issue that needs to be addressed as efforts are made to upgrade the control systems; and, that is data accuracy. Before any automated system can serve the use effectively, the data input must be accurate. How accurate? Over 95% accuracy is the accepted number. Developing new systems without accurate input data is a waste of effort. The point is that efforts to improve record accuracy must run concurrent to systems design and in fact, must be successfully completed before the new systems are implemented.

#### SUMMARY

As the volume of business grows in the face of an increasing need to more closely control costs, a way must be found to automate the company's control systems. For upgrading an overall manufacturing resource planning system, the best approach is to modify existing vendor software packages. To do this in a shipbuilding environment requires a means for developing structured bills of material. The production work order system can be used to provide this element of the control system. A review of the company's total information needs must be carried out by a top management team. Educational programs are needed to upgrade in-house personnel in the latest manufacturing resource planning techniques. These efforts provide the base for acquisition of the appropriate vendor software to make up an automated control system for production and materials in small shipbuilding companies.

## A CASE STUDY USING MODELS IN THE SHIPBUILDING INDUSTRY

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### ABSTRACT

Engineering models can be a better way to accomplish project objectives and open new doors for improvements in operational and management techniques. Thinking must be changed from studying and designing on paper to designing on a model. Initial modeling efforts may be difficult but some of the problems can be reduced by the lessons learned. When an appreciation of the value of models and the ease by which they can be constructed is gained, the model will become part of the standard design procedure. The benefits are great.

## I. INTRODUCTION

We want to thank the organizers of this Conference for including a paper on engineering models. My recent experiences lead me to believe that the shipbuilding industry is on the threshold of developing new systems to aid design. Some of these new systems include models;

Most of the A/E firms in the United States currently use models. Some of the major A/E firms in the United States are making use of engineering model/computer systems and have been for many years. The shipbuilding industry, including, the. Navy, the naval architects, and the shipbuilders, can learn from things already happening. Some are, for instance, a report from Odense Shipyard states, "The Odense Shipyard has developed perhaps the most unique integrated piping design/engineering systems, in that the computer-aided system is based on the use of: 'scale models. "

When asked if we would present a paper at this Conference, we gave considerable thought to the commercial aspect of our message. Let me say now - yes, we will sound like we are selling the model concept - and maybe we are. But today, with the emphasis on labor cost and safety, and other problems related to improving design and productivity can you afford to overlook any tool that improves performance?

## II. BACKGROUND

### A. HISTORY



Engineering models have been around for about 30 years. The original models were built from wood, plastic, and metal and were crude and inaccurate by today's standards. These models were built from finished and checked drawings. It was not until the late 50's that models started to gain acceptance as a piping design tool. This was primarily due to the fact that the model was taken out of the model shop and placed on the design floor. Other contributing factors were the increased availability and range of mass produced model parts, the simplicity and accuracy with which models could be built, and the demand by users.

## B. WHAT ARE ENGINEERING MODELS

Engineering models have been referred to as 3D drawings and scale reproductions. However, today the engineering model is being referred to almost universally, as a communication and design tool.

## C. WHY USE MODELS

Engineering models are bridging the gap between design, construction, and the client. Engineering models can be a better way to do things and can accomplish design, construction and plant operations objectives more effectively. Let's look at three areas where models can play a key role.

### 1. Design

Today, designing is more involved and complicated. Detailed engineering drawings are only fully comprehended by a trained few. And when these engineering drawings number in the hundreds and thousands, it is only the trained few that can visualize all of the details and arrive at a clear picture of the whole project. Design quality and performance are vastly improved when using a model because designers and engineers can more quickly see alternatives.

a. Confidence

Conflict free

Costly interferences are eliminated. You have a conflict free design.

- Quality

Models improve the quality of design. Mistakes are made on the model and not during construction.

You will have confidence in your design. You know you will end up with better arrangement of equipment and piping systems and know that the plant can be built.

b. Contribution

- Visibility

Look at it this way, all disciplines are shown on a single drawing - the model. The draftsman and designer can contribute more to the total project in a shorter period of time. A model gives better visibility of the project. You can see things on the model that you cannot see on paper.

- Accelerates schedules

Models will help to speed up design. No changes upon changes. The designers see the total picture. Coordinating time is reduced throughout the project. Decisions are made faster.

Normally a designer should wear 3 hats.

First he must design the plant. Then he must put on his constructor's hat and evaluate the design in terms of construction. Then he must place himself-in the position of the operator and determine if the plant can be operated and maintained. The designer can do all of these things better and make a greater contribution when using a model.

### C. Communication

- Management Aid

Management is able to obtain maximum use of all their people's talent and experience. The model helps to

plan, schedule, and re-assign work priorities.

- Involvement

Managers become more involved because they can see progress and problems and can make decisions faster.

- Review

How do you conduct a design review without a model?

- Status

The model clearly shows holdups. No surprises - you can see what is happening. What better way as a manager or project engineer can you review progress?

There must be communication to convert the ideas to design. With a model you have improved this process. You have a tool that provides a common ground for communicating.

## 2. Construction

The greatest cost saving attributed to a model is from its uses as a construction aid. A model allows all crafts and subcontractors to see the overall scope of the project and minimize the interpretation of the construction drawings.

## Planning/Scheduling

Construction schedules are prepared more quickly and more reliably from using a model. Rescheduling is accomplished more effectively.

## Construction management

A model helps to understand your plant better. You can prepare better specs for procurement. Subcontractors can see each others requirements and can interface better.

## Input to design

The construction superintendent can make input to design early in the design phase, rather than during construction.

## Erection sequence

Models aid in effectively locating construction equipment. At the construction site a model is worth a pile of drawings. With today's complex processes, no single person can visualize a complete plant. A model lets every body see the same thing.

### 3. Plant Operations

With emphasis on safety and labor costs, the model provides an extra payoff when it is used to aid the planning and operation of the plant.

#### Operator training

Operation training manuals can be prepared while the plant is being constructed. Personnel can be oriented to a new plant and equipment long before it is placed in operation.

#### Safety studies

Safety studies can be conducted and necessary precautions identified and procedures prepared.

#### Maintenance studies

Future maintenance studies can be conducted and maintenance procedures prepared. Maintenance is more easily understood.

The model can be used to plan start up sequences. After that the client can use the model for all future planning and studying of changes and continuous operator training.

### III. MODELS AS RELATED TO SHIPBUILDING

The complex, curved structure of the hull of a ship presents a major problem to the designer and the builder. Visualizing a three dimensional design within a non-rectangular space is not an easily developed skill. When the space is then filled with machinery and equipment connected by miles of piping, tubing, ducting and electrical cables, the problems are compounded. This is then further complicated by specialists within their own fields working separately on parts of the design. Coordination of these efforts is a major problem.

In order to coordinate the efforts of the designers and prevent interferences from occurring in ship, engineering drawings, composite drawings have been traditionally used. These drawings show all of the piping, duct work, cable ways, etc. in an area on one drawing. As can be imagined, the composites become very complex and difficult to read. Errors can readily creep in. Further, it is a demanding but essential task to keep the composite drawings current as the job progresses.

Models have been used in past ship design efforts by various shipyards and design agents and are being seriously considered as a regular design tool. In addition to the tangible benefits of improved design, lower construction costs, and as an operator training aid, ship engineering models have various intangible benefits.

Some of the intangible benefits are like an insurance policy -- the value is evident at a later time. We do know that models offer a better design approach than drawings. The best design can be produced in the shortest possible time. Models allow the better use of the

available people. Most of the experienced people are in a position where they have little time to review drawings. If something is wrong and a model is being used, the problem will be found while there is still time to do something about it and before costly construction changes are involved. But, perhaps the greatest benefit of a model is its use as a communication tool.

#### IV. CASE HISTORY

Sun Ship like probably all shipyards has used modeling for various aspects of ship design and construction for many years. These models included hull form, structure, piping and machinery. While some models such as for anchor handling have been used for almost every design, models of the machinery spaces have been used only sporadically. Recently Sun Ship did use models to aid in the design of the machinery spaces and pump room of a specific project, the Medium Class Hopper Dredge currently under construction for the Corps of Engineers.

While there may be a tendency to equate a dredge with a barge, the MCHD is not simple. It is in fact a very complex ship -- in structure, machinery and piping. The basic layout is a more or less conventional machinery space aft and a large, complex pump room forward connected by highly congested accesses through the hopper space void areas.

Sun Ship contracted with USA Models to build models of the Pump Room, Engine Room and a section of the Hopper Area. These models were not included in the initial planning for the project, but were added as the need for them was recognized. The first section to be modeled



was the hopper area. This was triggered when a change order required the installation of additional piping through already congested hopper voids. It was also recognized that bringing this piping into the engine room and pump room might involve problems and that therefore an examination of the bulkhead penetrations might be valuable. The modeling effort rather rapidly expanded to include the complete pump room and engine room as well.

The design effort for the MCHD was performed by a design agent, J. J. McMullen Associates and was done at their New York and Newport News offices. The models however, were built at Sun Ship and at the USA Models plant in Pennsylvania. As a result, the models were not physically available to the JJMA designers on a day to day basis as the design effort progressed. The models therefore served more as a check on the design rather than a designing tool. There were however numerous occasions when valuable design input was obtained from the models.

The prime purpose in building the models was to reduce the engineering problems which would be encountered during construction of the ship. This of course is expected to decrease the rework and delays which might otherwise be encountered. Productivity improvements are expected and are being achieved from both the lower level of unplanned work and the better schedule adherence than would otherwise have been encountered.

The model technicians reported a total of 412 problems in the construction of the three models. The reported problems were fed back to the design

agent as they were encountered. Of the total, 33 problems were reviewed by J. J. McMullen Associates and evaluated as not requiring any change to the drawings.

A total of 379 problems reported by the model technicians resulted in one or more changes to a drawing.

The types of problems uncovered included:

- Structural design errors

- Foundation problems

- Interferences

- Pipe detailing errors including

  - Incorrect dimensions

  - Flange orientation and attachment problems

- Material list errors

  - Holes list errors

While none of the problems were momentous, if they were allowed to reach the construction stage without correction, the total impact would have been appreciable. Consider for example, the relatively simple problem of failing to leave a loose flange on a length of pipe which has to run through a hole in a structural member. How many manhours does it take to correct the problem when the prefabricated pipe can't be installed at the job? Would 2 men for 1 day or 16 manhours be reasonable? At that rate, the flange error could cost \$300-400 in labor alone. The flange error will also have a schedule impact. The work on that part

of the job at least will be a day late. If that can't be made up or absorbed by a buffer, the-delivery could conceivably be delayed by a day or even more. The actual cost of the flange error, like the proverbial horseshoe nail, could be great. When multiplied for a series of small errors, the total cost could grow geometrically.

Due to the usual limited available resources and the size of the task, a detailed cost benefit analysis for modeling of the MCHD was not attempted.

## V. LESSONS LEARNED

Modeling can make a significant contribution to the shipbuilding industry -- and can make that contribution today. There is no need to wait for future developments. It is possible to gain greater benefits from modeling than were achieved in the MCHD project. Some of the actions needed to obtain the greater benefits possible from modeling are:

- A. Include modeling in the initial plans and schedules. Model building takes time. To obtain the full value from a model, the building of the model has to be planned and scheduled as part of the overall project schedule.
- B. Design with the model. The model and the model technicians can be a great assist to the designers. The design effort will go faster and with fewer errors.
- C. Introduce model building to the organization with care. The modeling function can be perceived as a job threat to the designers. For

maximum benefit however, the designers have to use the model and work with the model builders as a team.

- D. Locate the model technicians physically with the designers. Physical separations undermine the effort to have the designers and model builders work as a coordinated team.
- E. Designate a coordinator -- with some clout. Someone has to keep the information flowing both ways and to smooth out any problems between the designers and the model builders as soon as they develop.
- F. Establish and publish procedures for the model technicians and designers to follow. Confusion as to what they can expect from each other can cause a rapid breakdown of any cooperative spirit.
- G. Set specifications for the model and the model technicians. This includes the areas to be modeled, the scale and color schemes. Set tolerances for the model. Model makers can work to tolerances far closer than those to which ships are built. Working to this degree of accuracy is wasted effort from a shipyard's point of view.
- H. Prepare a schedule and establish a budget for the model and then require the model builders to adhere to them. Model building is much like any construction project. If you do not exercise control, the costs will grow and the schedule will slip.
- I. Don't start a complex design project without a model!

## VI. THE FUTURE

During this symposium, we have heard many exciting papers on the use of computers to improve productivity in shipbuilding. Unfortunately, many of the benefits of the application of computers to ship design still lie ahead of us and some significant problems remain.

Modeling, while perhaps more prosaic than computer applications, is a design tool available to the shipbuilding industry today.

A skilled model builder is actually a designer working with plastic and solvent instead of paper and pencil. Some of the advantages of the three dimensional model over the two dimensional drawing have been covered today. There are some disadvantages as well.

Models take up space and are not portable. Some of the other concerns might be that changes to the model may be more difficult to make than to a drawing. Furthermore, even when modeling, working drawings or sketches are required for shop use. Transferring the design from a model to a drawing can result in errors and mistakes.

An ideal system for engineering design would incorporate the presentation advantages of the three dimensional model, the ease of change of the pencil and eraser and the automatic preparation of drawings of computer assisted drafting. The computer holds forth the promise of evolving into such an ideal design system, but it is not there yet. Shipboard machinery spaces are still too complex. However, a combination of models and computers can be used today and can achieve an approximation of the ideal system.

Physical models have proven to be excellent inputting devices for computers. With the data from the model, the computer can perform the necessary calculations and prepare the paper output. In this sense, computers and models are not really competitive techniques but are actually complementary. The synergism of using a combination of the two techniques together can achieve a level of effectiveness greater than the simple sum of either technique alone.

Some day, we would expect computers to supplant model building. At that time, the model builder and the designer/draftsman will probably have merged into a single profession -- the computer based designer -- a designer who works with complex, 3 dimensional designs without ever touching plastic or solvent, paper or pencil.

John belongs to the American Engineering Model Society, a professional society composed of model technicians and management people. The primary aim of the society is to promote and improve the modeling techniques and contribute to quality design and productivity. In 12 years of holding formal seminars and presenting technical papers, only one paper has been presented having to do with shipbuilding. That paper was by Vickers Ltd. in 1972. To our knowledge only one book was published and that was by the Maritime Administration in cooperation with Todd Shipyards, published in 1974. It is one of the finest books available on models.

Planning and imagination must be applied constantly to improve productivity, keep costs down, and create producible designs. In the power and industrial plant design and construction industry, models are the heart of a vital process and are helping to create quality designs and aid in construction.

We believe that the Shipbuilding industry is on the verge of a rapid expansion in the use of engineering models.

Thank you.

#### POST SCRIPT

A film is available through the AEMS. It is about Stone & Webster's engineering model program.

Also a variety of literature is-made-available through the courtesy of the American Engineering Model Society and Engineering Model Associates.

#### ACKNOWLEDGEMENT

Special thanks to Art McCoy, Director of Marketing, Engineering Model Associates, and to the American Engineering Model Society.

## PRODUCIBILITY FROM CONCEPTUAL DESIGN TO SHIP CONSTRUCTION

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### ABSTRACT

Producibility concepts may be applied in a variety of ways. Three main classifications are identified:

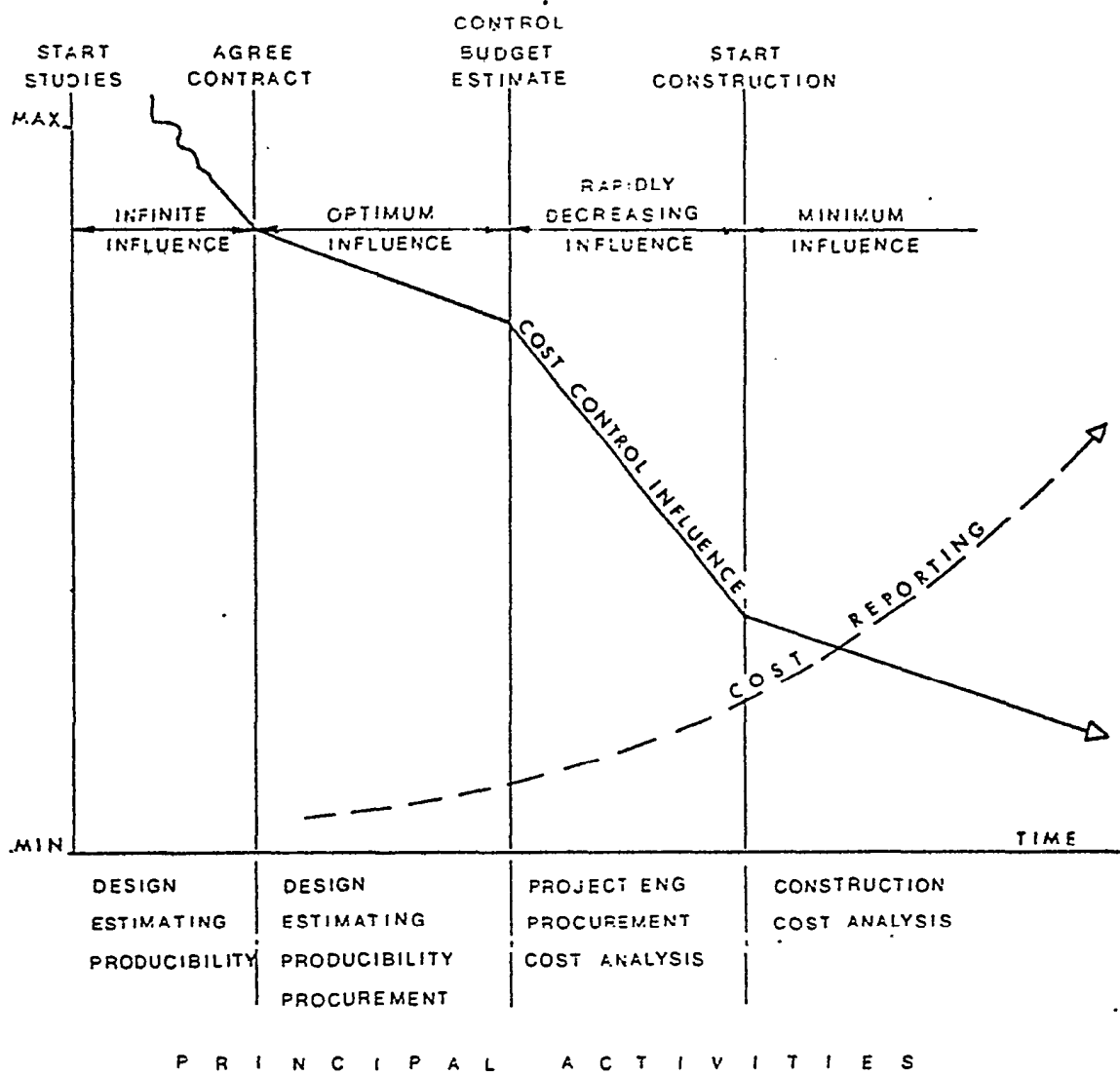
1. At the conceptual design stage
2. At the design development stage
3. As a method of reducing operational costs by removing work content, shortening the construction time and rationalizing material requirements of existing designs.

This paper reviews the effectiveness and likely benefits to be gained from these three approaches and examines design engineering, production engineering, facilities engineering and personnel engineering as applied at these three levels.



Figure 1

# COST CONTROL POTENTIAL



The image contains three technical drawings of a ship's hull:

- Plan View (Top):** Shows the top-down layout of the hull. It features a central longitudinal section with a keel and two main hull sections. The hull sections are divided into three rectangular areas labeled "No 1 Hatch", "No 2 Hatch", and "No 3 Hatch". The hull is wider at the bow and tapers towards the stern.
- Longitudinal Section (Middle):** A side view of the hull showing the internal structure. It includes the keel, the hull plating, and the internal bulkheads. The hull is shown in a cross-section view, with the internal structure visible. The hull is wider at the bow and tapers towards the stern.
- Transverse Section (Bottom):** A cross-section of the hull at a specific point. It shows the hull plating, the internal structure, and the hull's width. The hull is wider at the bow and tapers towards the stern.

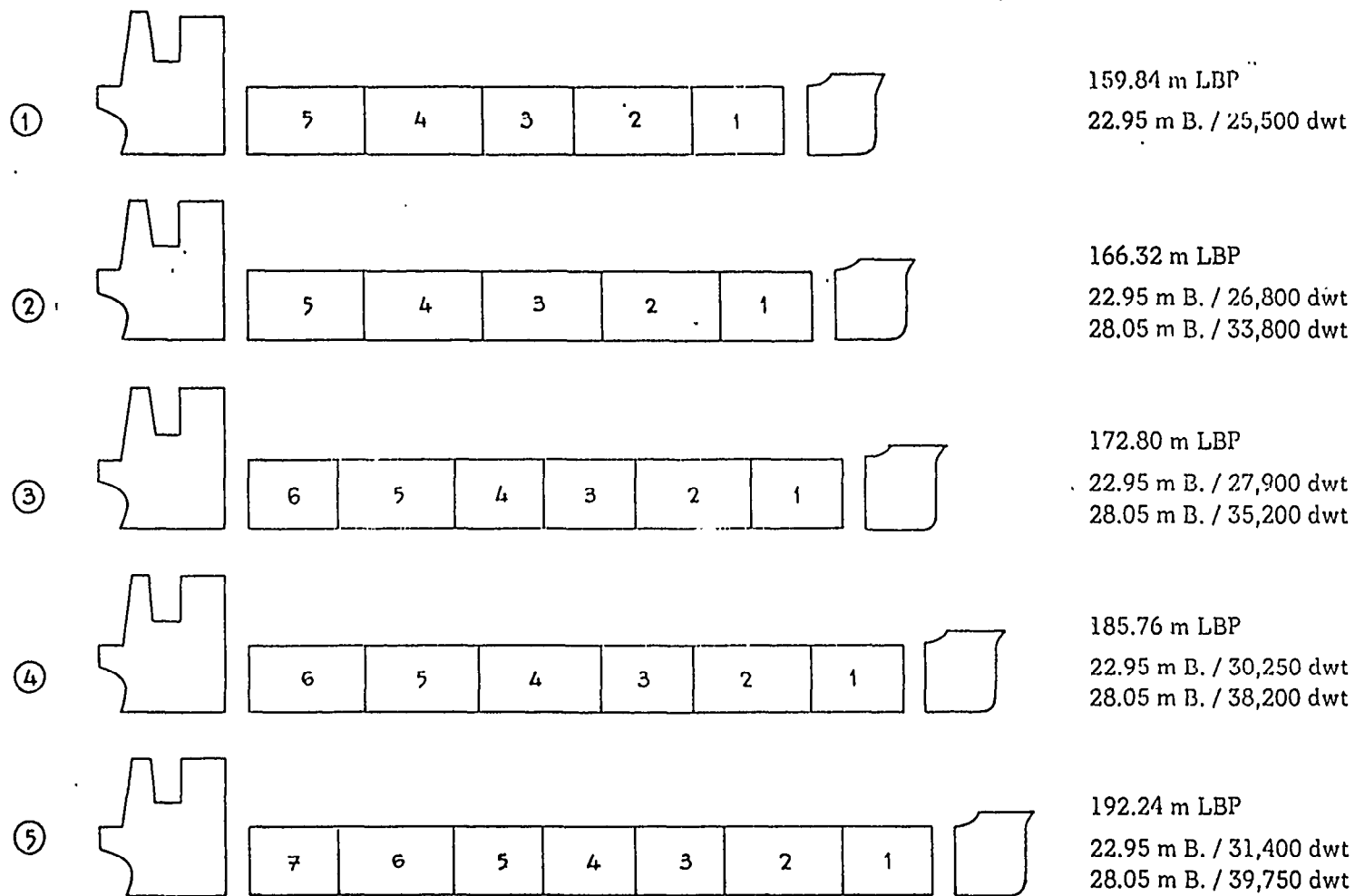
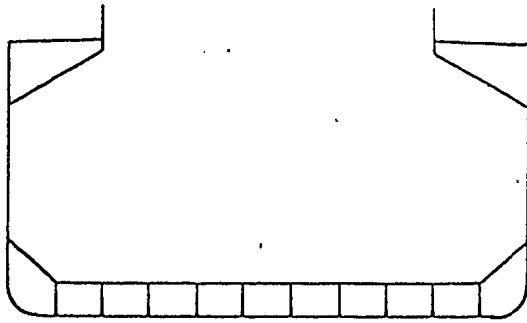


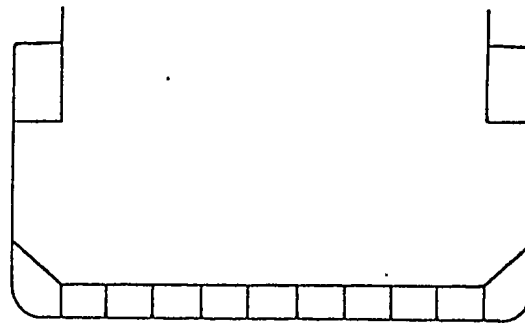
Figure 3

### Length-Dead weight Options

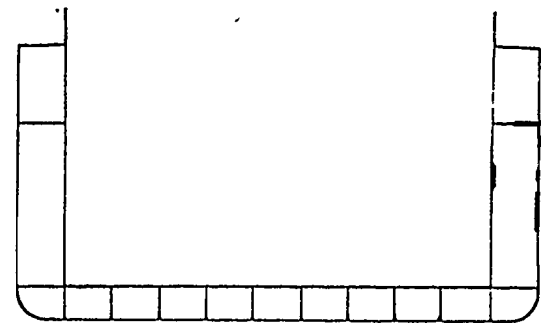
28.05 m B.Mld.



CONVENTIONAL

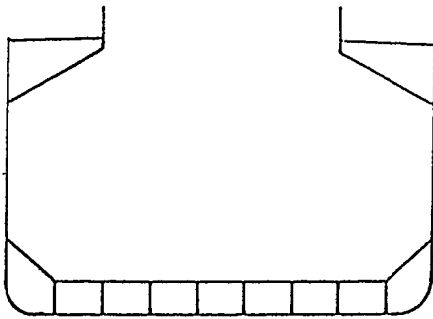


WIDE HATCH

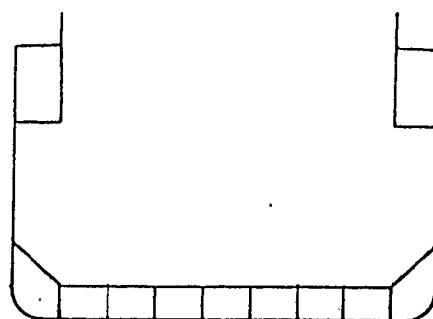


FOREST PRODUCTS

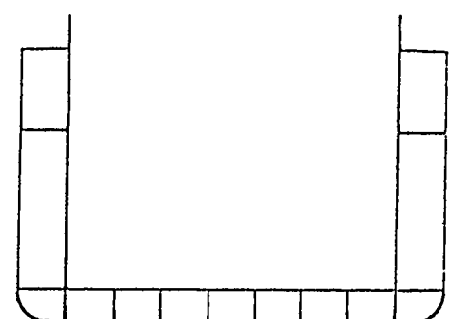
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CONVENTIONAL



WIDE HATCH

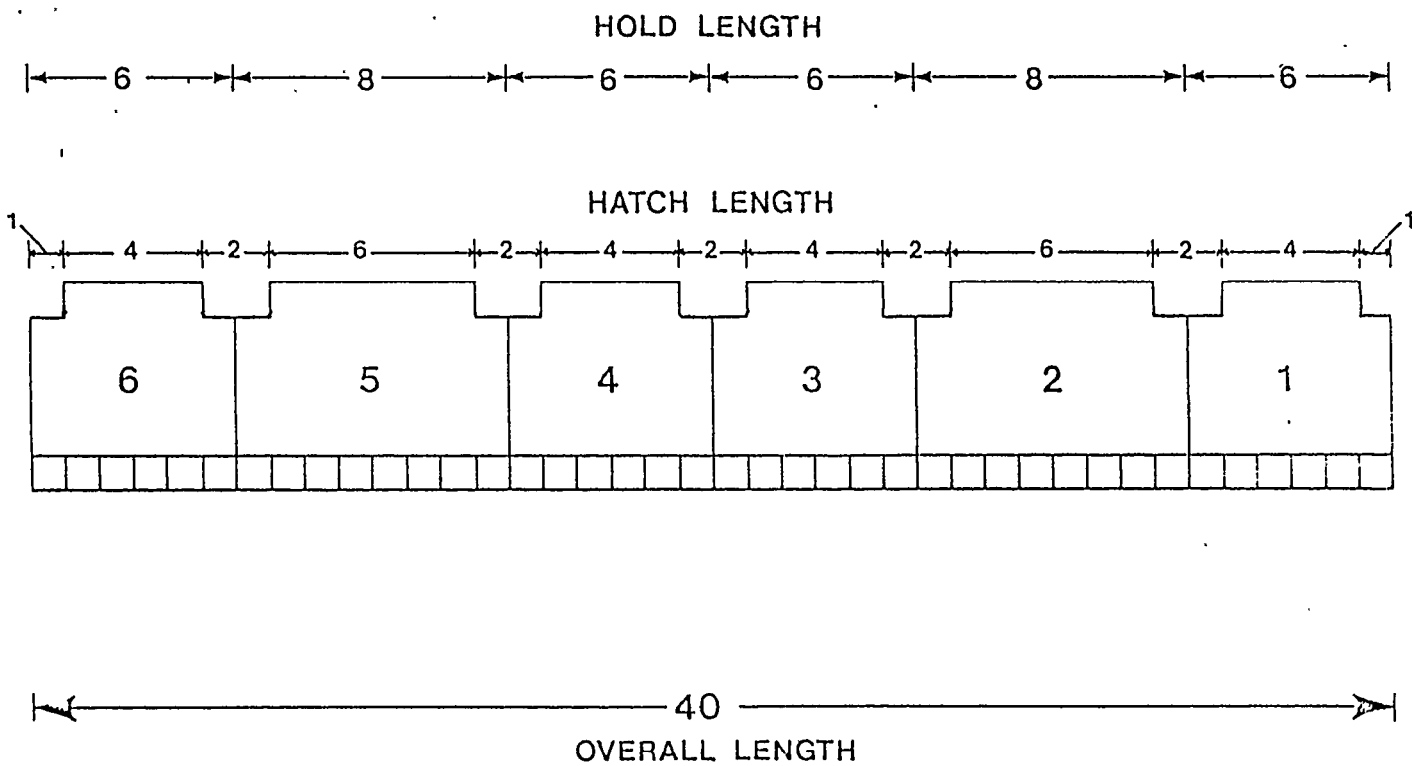


FOREST PRODUCTS

### Beam & Type Options

Figure 4

Multiples of longitudinal  
modular dimensions in:



172·80m LBP VESSEL - CARGO HOLD SECTION PROFILE

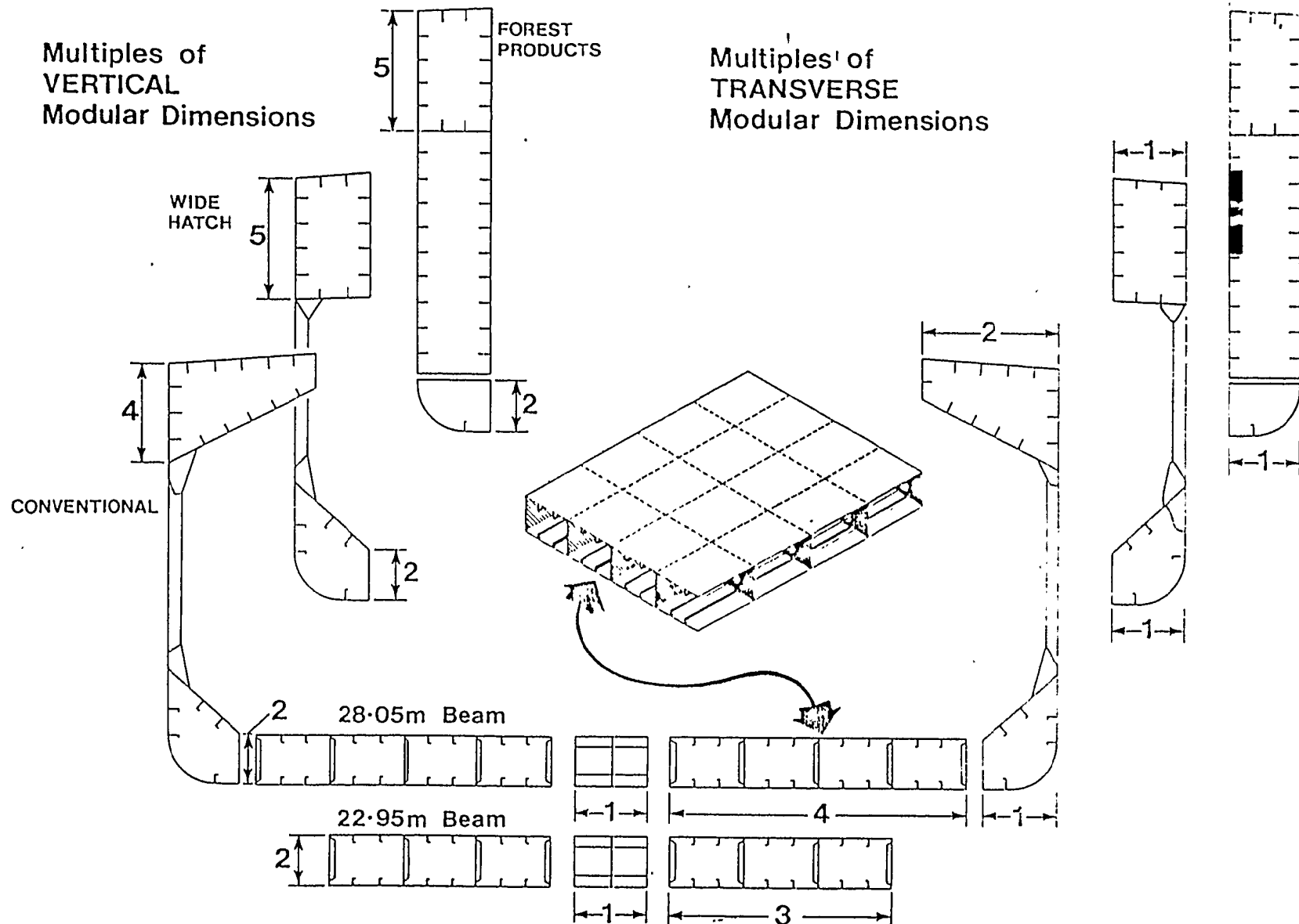


Figure 6

ALTERNATIVE MIDSHIP SECTIONS

Figure 7 .

BLOCK WEIGHTS:-  
 E = 4 wt.  
 C = 75 T.  
 K = 125 T.  
 D = 80 T.

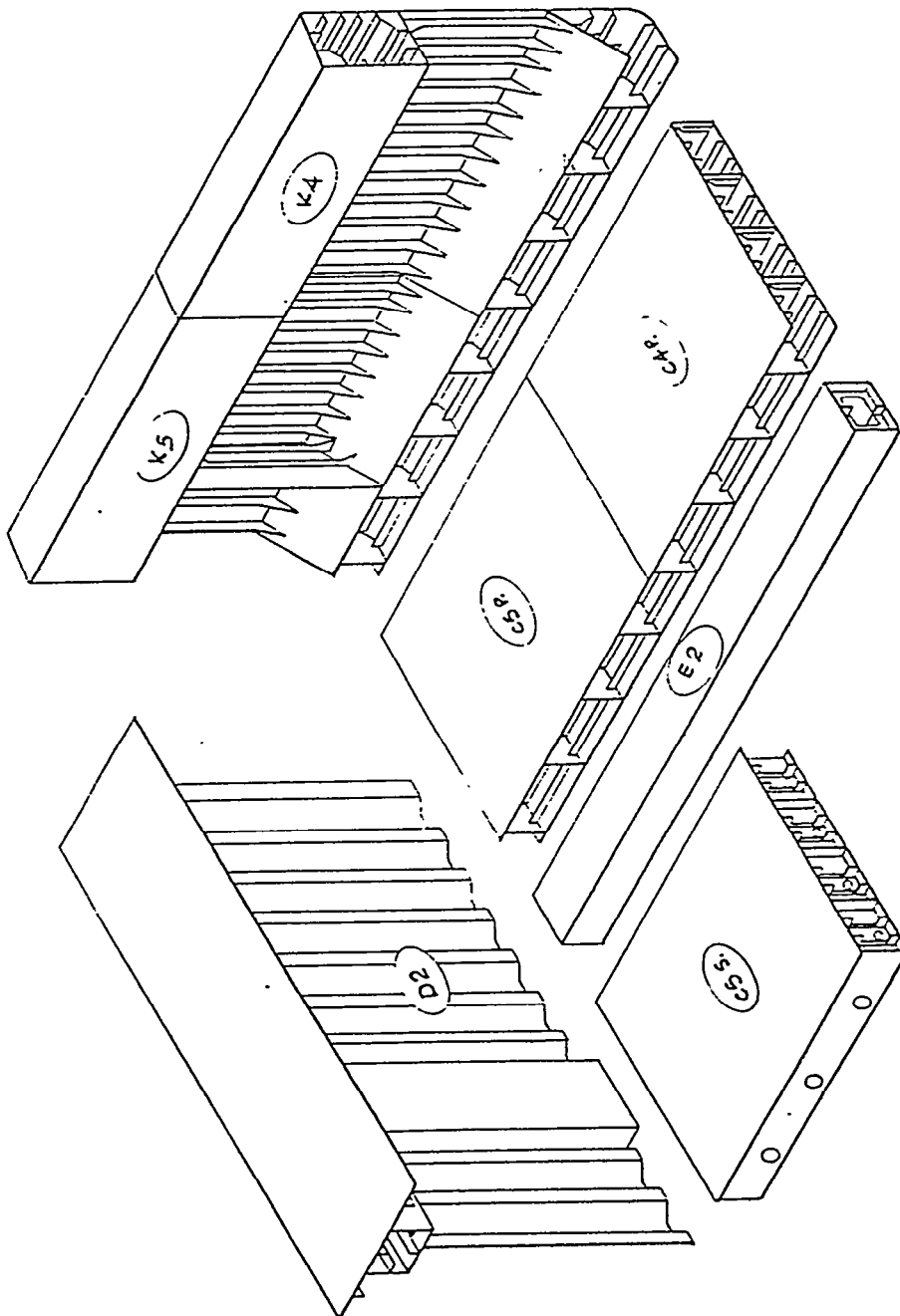
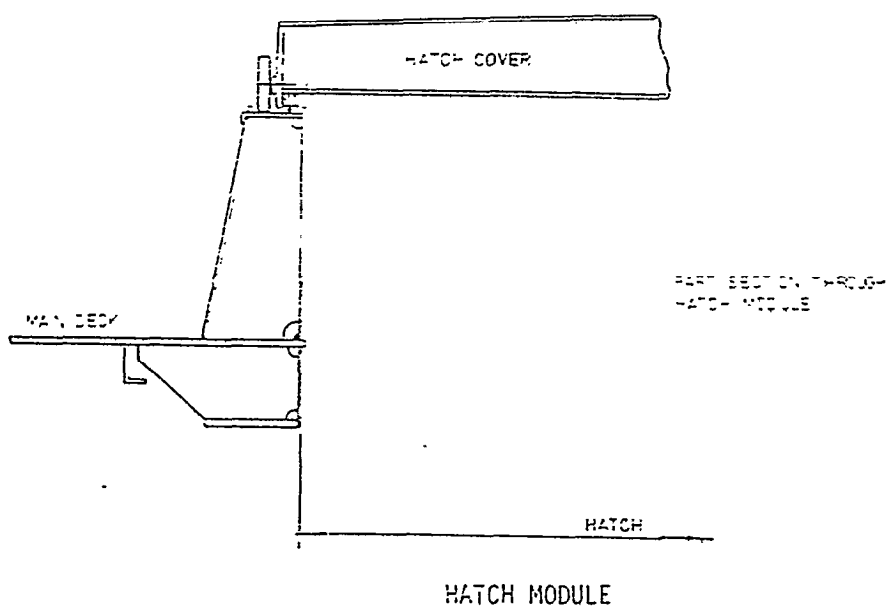
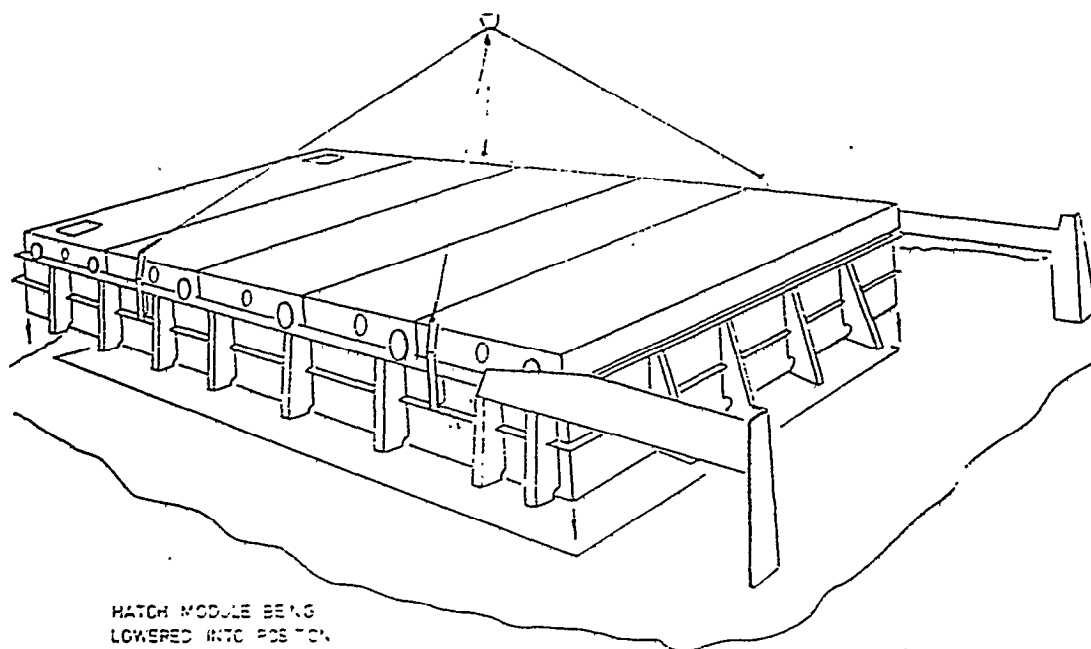


Figure 8



Hatch covers and coamings are assembled and tested 'off site' and delivered to the ship under construction.

Final Welding of the coamings is completed and module welded in position



Figure 9

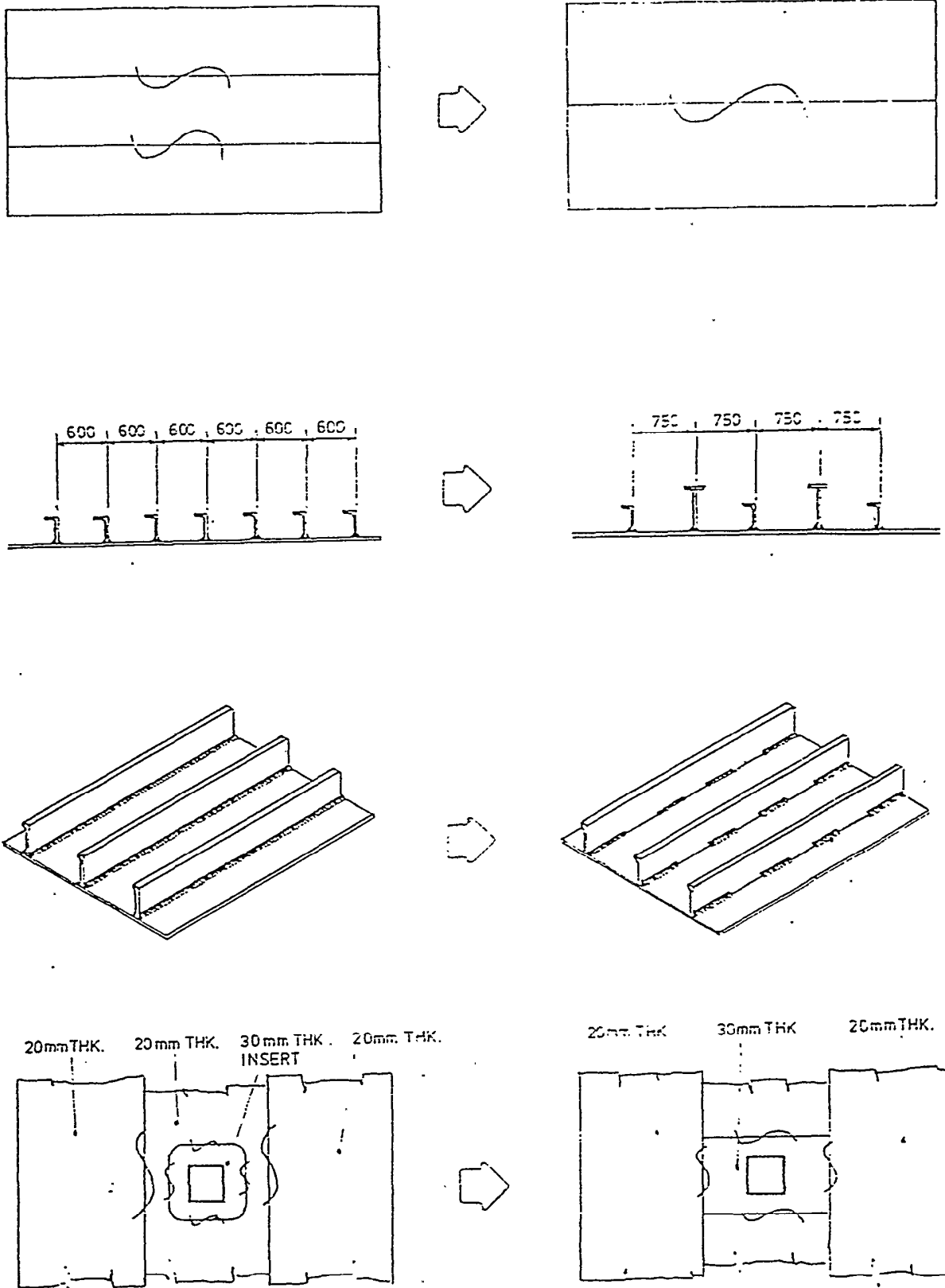


Figure 10

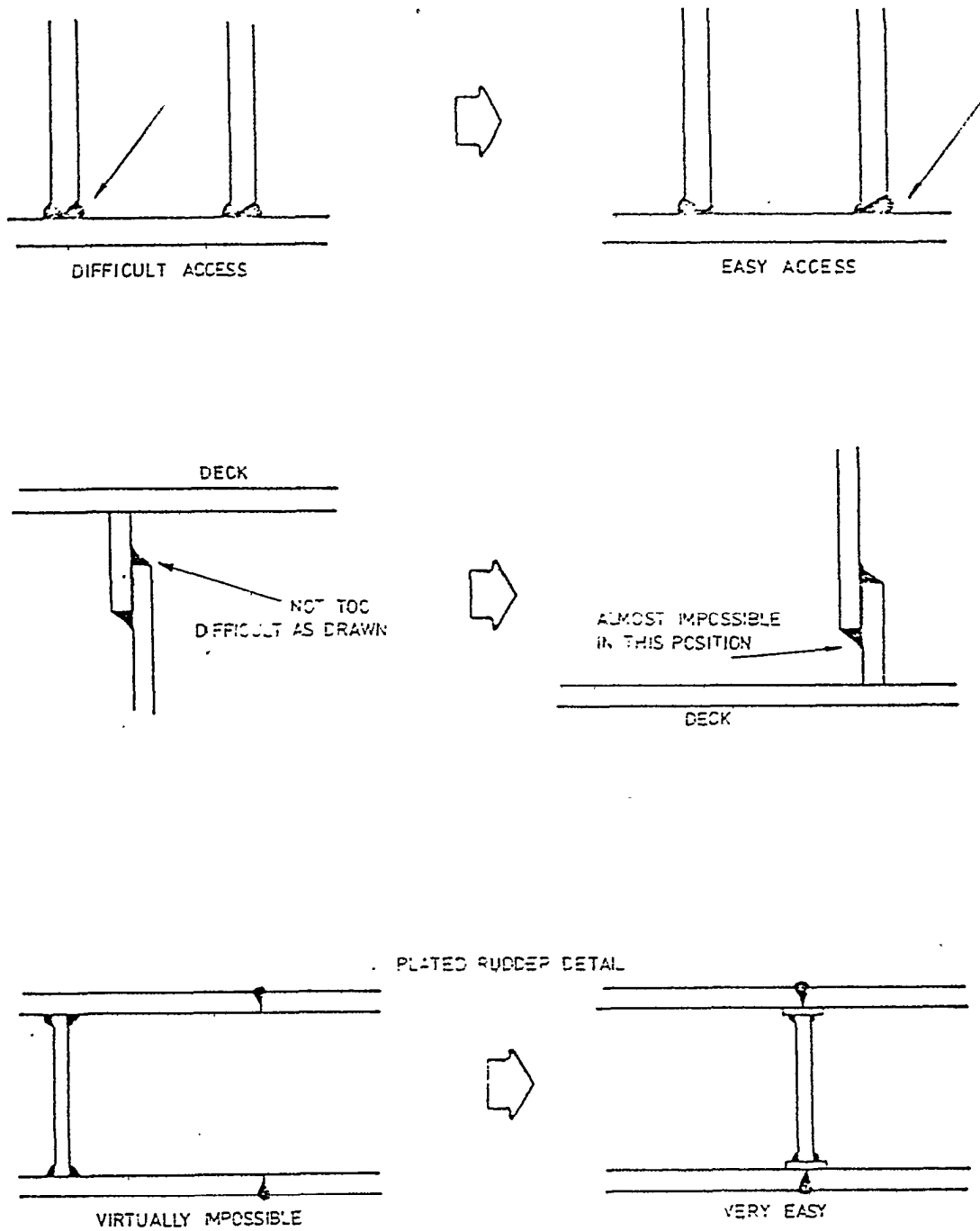


Figure 11

OPERATIONAL CHARACTERISTICS OF  
SHIPBUILDING

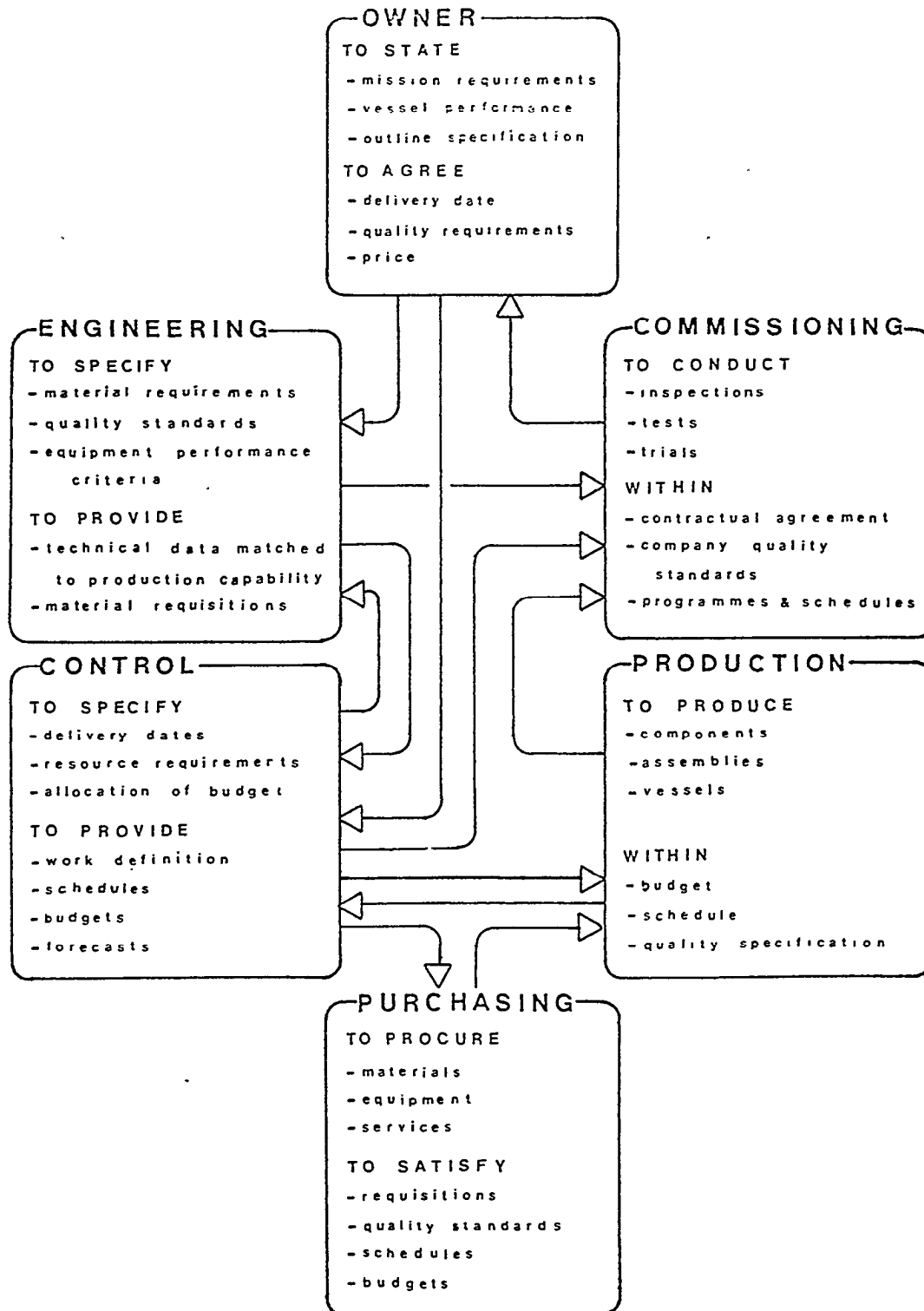
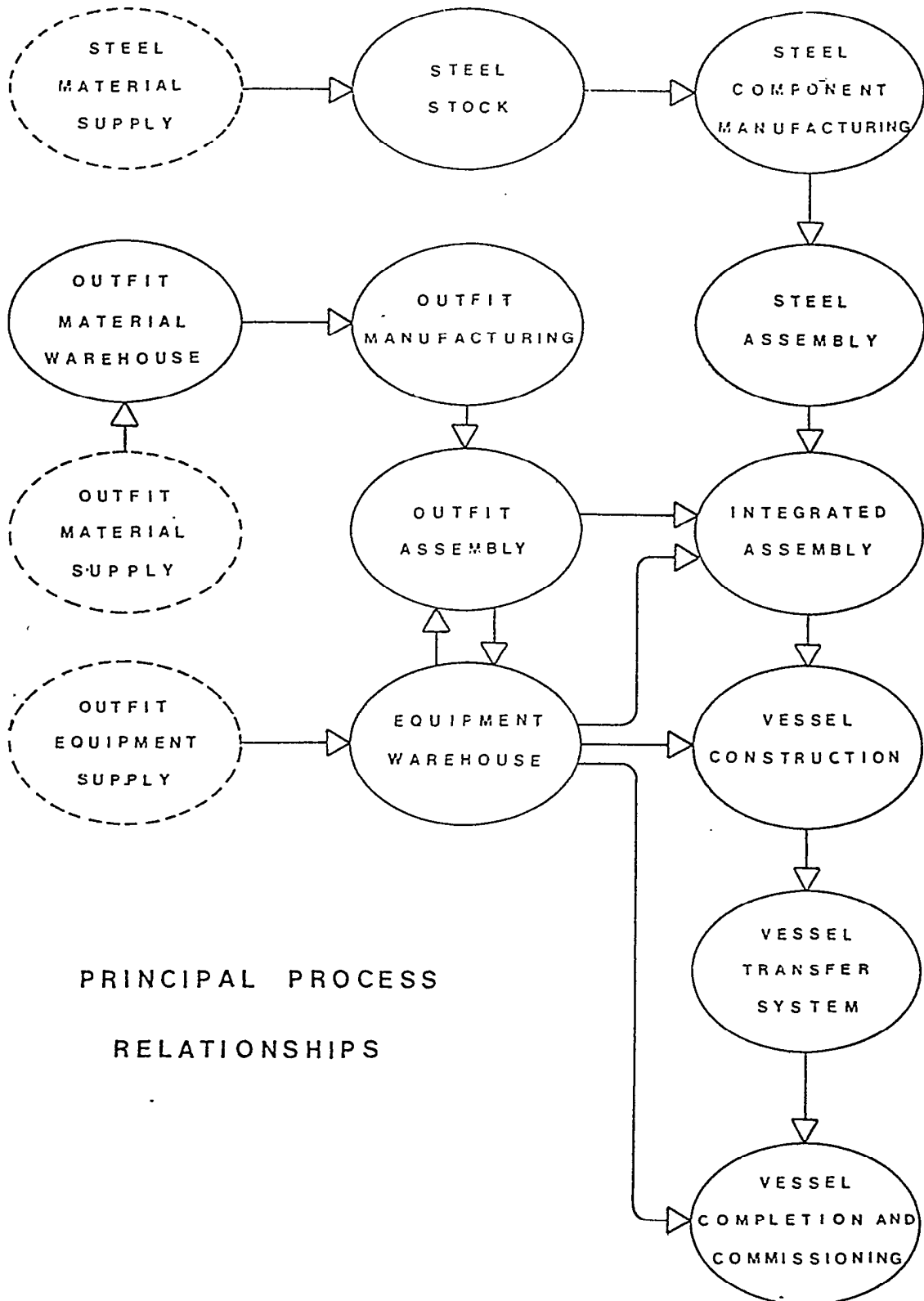


Figure 12



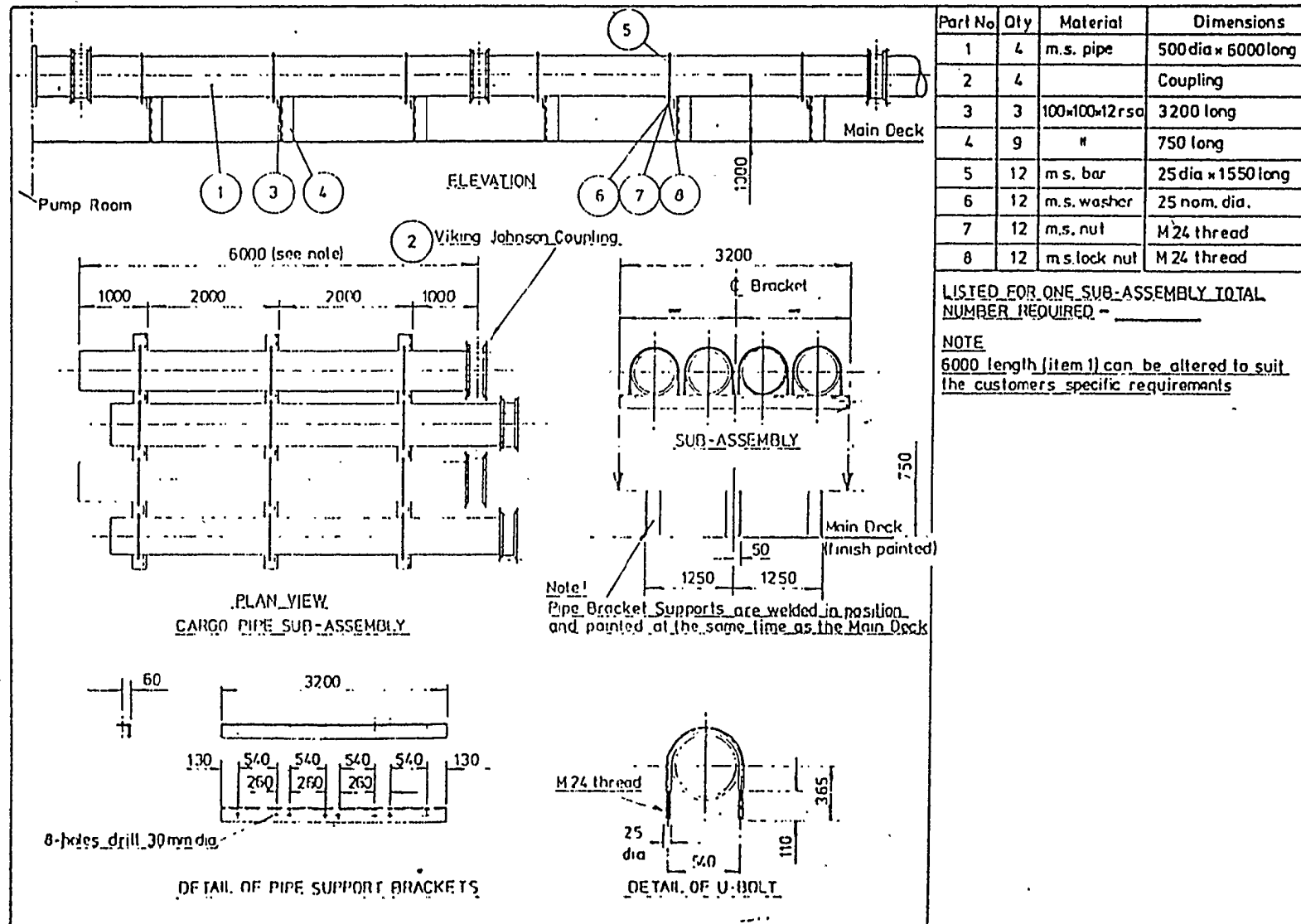


Figure 13

Figure 14

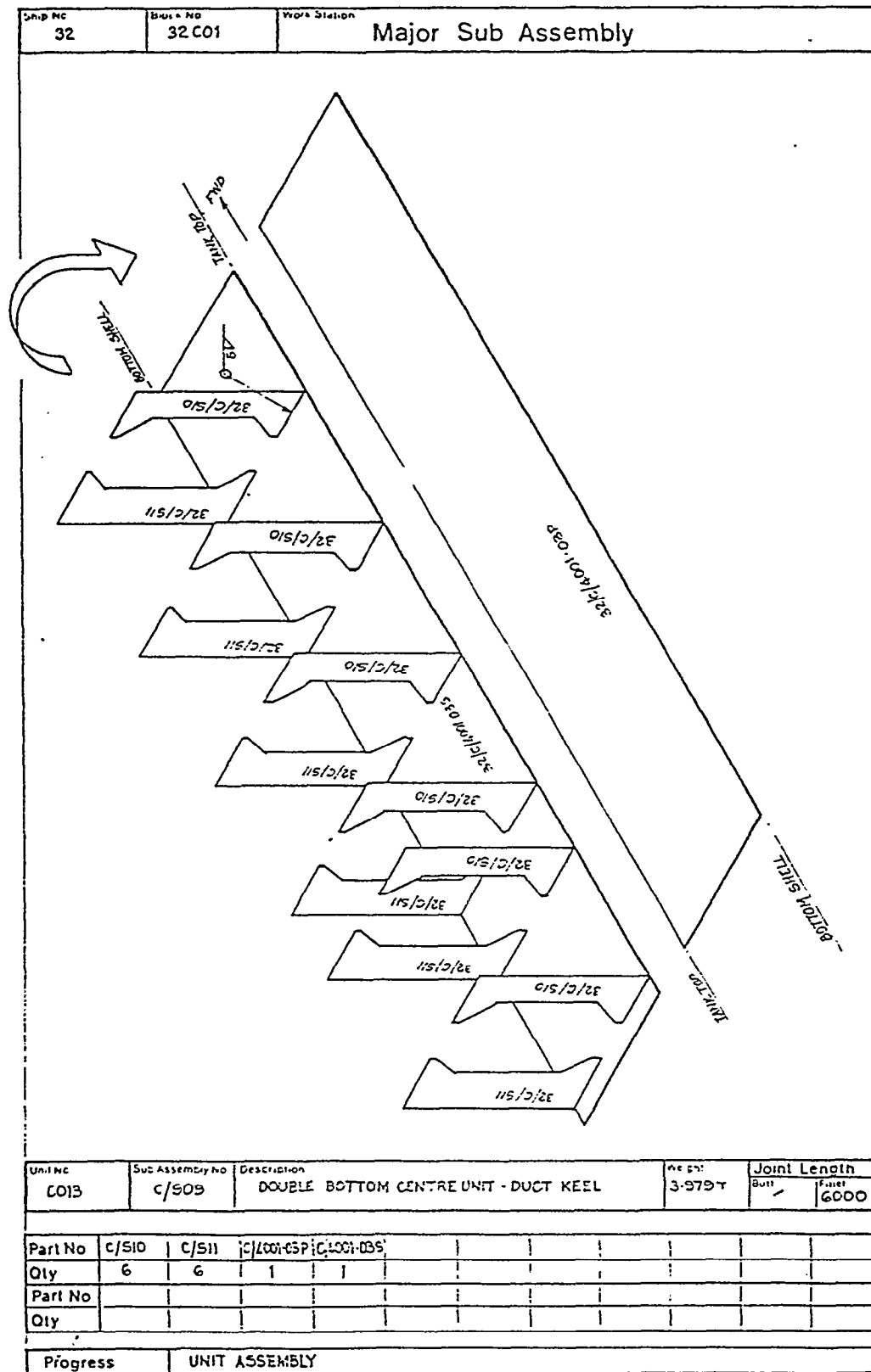


TABLE 1  
DESIGN CONSIDERATIONS

- a) Operational requirements study.
- b) Principal dimensions selection.
- c) Body plan.
- d) Form variation.
- e) Hydrostatic calculations.
- f) Main dimensional analysis.
- s) Freeboard.
- h) Subdivision.
- i) Propulsion system.
- j) Capacity calculations.
- k) Preliminary selection of equipment.
- l) Machinery component selection.
- m) Electrical component selection.
- n) Weight and C.G. calculation.
- o) Trim and stability calculation.
- p) Damaged stability calculation.
- q) Strength calculations.
- r) Speed prediction.
- s) General arrangements.
- t) Machinery systems balance calculations.
- u) General arrangement of engine room.
- v) Pipe systems.
- w) Electrical systems.
- x) Technical specification.

TABLE 2  
PRODUCIBILITY CONSIDERATIONS

- a) Principal Dimensional Check
- Launch/float out.
  - Navigation.
  - Crane cover and clearance.
  - Ground/dock loading.
- b) Vessel Characteristics
- General arrangements.
  - New/unknown type.
  - Construction philosophy.
  - Zone configuration.
  - Special technological requirements.
  - Structural configuration.
  - Hull form.
  - Supplier/subcontract content,
  - Technical interdependence.
  - Modularity and standards.
  - Balance of work content.
- c) Facility Characteristics
- Berth/dock dimensions.
  - Tidal influence.
  - Accessibility.
  - Levels of technology employed.
  - Human skills.
  - Working practices.
  - Resource balance.
  - Manufactured products.



Table 2 cont'd

- Material storage.
- Crane capacities.
- Internal transport.
- Material dimensions.
- Standards.
- Production capacity.

d) Assembly Philosophy

- Steel.
- Outfit.
- Pipework.
- Engineering.
- Electrical.
- Subcontract content.
- Painting.
- Zone outfitting.
- Block breakdown.

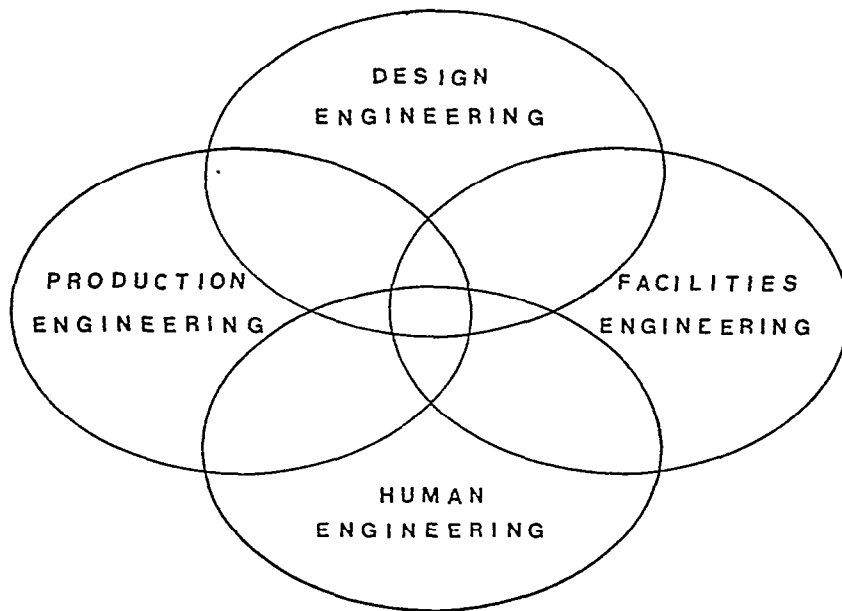
e) Manufacturing Philosophy

- Standards.
- Range of products.
- Modularity.
- Material definition.
- Jigs and tooling.
- Technical information.
- Balance of manufacturing resources.
- Subcontract content.

f) Planning and Control

- Programme and cost.
- Sequence of work.
- Work content analysis.
- Productivity.
- Sensitivity.

Figure 15



## COMPUTER ASSISTED PROCESS PLANNING: A FIRST STEP TOWARD INTEGRATION

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### ABSTRACT

Computer assisted process planning can be a first step toward the integrated use of computers in the design and manufacturing process to improve productivity in batch manufacturing. The key to the process of integration is a part feature recognition method to analyze and retrieve manufacturing processes and arrive at least-cost designs consistently linked to "best" manufacturing processes. Major problems are incompatible computers, software; and people.

The 1980 recession has served as a sharp reminder of the need for industry to improve its productivity to maximize the results of its investments in people, materials, and equipment.

Inflation and high interest rates have also created intense financial pressures on management.

While these factors have accentuated the need for higher productivity, they are waves on a stream which has been well defined for a number of years. They have been intermingled with other factors, such as shortages in skilled personnel and increased demand for specialized products. Certainly through most of the 70's, management has been driving to get more out of what it has to work with.

A trend in management's favor has been the remarkable advance of computer technology. As everyone knows, computers have been doing a lot more, in much less space, and at much lower costs. There are minicomputers available today which can do the work of the huge mainframe computers of only a few years ago. Computer power which costs hundreds of thousands of dollars or even millions within recent memory, can now be purchased for thousands of dollars.

Software - the systems and programs which put computers to work, has also become increasingly sophisticated. Computers can be programmed to perform many functions which were unheard of a decade ago.

Computers, or minicomputer to be more specific, were relatively slow in making their way on to the shop floor. In the early 60's, numerically controlled equipment promised to revolutionize manufacturing. While N/C certainly has had a significant effect on manufacturing efficiency, it has taken a great deal of time and is slowly approaching the potential its advocates once saw for it. Perhaps because of this experience, or because of the natural conservatism of batch manufacturing management and their cost consciousness, computerization did not gain rapid acceptance.

In very recent years, this has changed somewhat. Computer hardware prices fell to within the budgets of small batch manufacturing organizations, and software was designed to meet batch manufacturing needs.

To the buyer, however, contemplating the purchase of a computer system and/or a software system or systems is something like the purchase of stereo equipment. There is a great deal of equipment on the market, much of it differentiated only in subtleties. It is high technology being thrust on an industry which in many ways is relatively low technology - there are bigger and better lathes today, to be sure, but the basic principles of turning have not changed since the industrial revolution.

Even the most sophisticated buyer is confused by the complexities of the hardware and software being offered. The differences between systems are often so thin as to be irrelevant, and in many cases, in the isolated purchase of one system or another, one is "just as good" as the next.

The result has been an electronic Tower of Babel. A computer is purchased here, another computer is purchased there, and programs and software systems are created or purchased to perform specific functions. All is well, as long as the computer is used by a single department for a single function. As companies become more familiar with and comfortable with the computer, however, they rightfully want more for their money.

What they are discovering, is that the piecemeal approach to the use of computers has not increased productivity as they envisioned. The computers often do not communicate with each other. They have different kinds of databases,

programming languages, and other aspects which make them difficult if not impossible to integrate.

It is something like trying to increase the flow of a liquid through a pipe. An obvious answer is to make the pipe bigger. A system, such as a computer assisted process planning system or a material requirements planning system or a computer graphics system is purchased to "make the pipe bigger". Unfortunately, it only makes one portion of the pipe bigger and there are still sections which have not been increased. As a result, the amount of liquid coming out the far end is not increased either. All that we have done is make the pipe more expensive.

This is the situation in most of American batch manufacturing today. Many computers, many software systems, but little communication and little long term overall impact.

The answer to this problem lies not so much in the development of new systems but in the implementation of integrated approaches to the use of computers in batch manufacturing.

There are relationships among everything done in design and manufacturing. Computers make it possible to recognize and understand those relationships, and to put them to work to increase productivity.

Computer assisted process planning can help to lower production costs and increase productivity by reducing the amount of time required to prepare process plans and related documentation. At the same time, it is much more useful when it can also be used to take advantage of a company's best manufacturing capabilities and practices, by producing optimal routings - routings which move work across the shop floor in the most efficient and least costly manner. To do so, of course, the computer assisted process planning system requires information about the company's tools, its product mixes, and much else.

Computer graphics is a technology which is just now beginning to be felt in industry. As typewriters have disappeared from newspaper offices, drafting boards will someday be gone from manufacturing design departments. As reporters and editors work with electronic word processing systems, so too will design engineers work with computer graphics systems.

A computer graphics system greatly enhances the capabilities of the design engineer. He or she can solve design problems faster than was once imaginable. If utilized in isolation,

however, this increased speed and power can only lead to more and more design duplication. To be most effective, the computer graphics operator needs to have access to information about parts which have been previously designed (to avoid "reinventing the wheel"). Information about manufacturing processes and their costs is essential if design engineers are to create designs which can be produced most efficiently and at the lowest cost. Obviously, that kind of information relates closely to process planning.

Group Technology is another relatively new force in batch manufacturing. With the right Group Technology system, it is possible to create families of parts, define dedicated machine tools, and do a great deal more to bring mass production economies to batch manufacturing operations.

Again it is obvious, that a great deal of information is required to bring about such results. This information, about machine tools and their capacities and capabilities, least cost processes, product mix, etc. is much the same as the information required to maximize the effectiveness of computer aided process planning and computer graphics.

It is theoretically possible to create separate databases to gather and store the information required for each of these systems. The amount of money and effort required to do so would in many ways negate the advantages. It is much simpler, and much wiser to have a common base of information which these systems and others can use.

The key to such integration lies in the use of a common vocabulary as well as in compatible computer languages.

A universal coding and classification system can provide such a vocabulary. It can be likened to the hub of a propeller. (See Figure 1.) In terms of this discussion, the propeller blades represent computer assisted process planning, computer graphics, and group technology. As the hub of the propeller, the coding and classification system is common to all three and also links them together.

In order to do this, the coding and classification system must have certain characteristics. A simple parts recognition system, for example, would not do the job. Information about the manufactured characteristics of the part is essential, along with other information relating to the kinds of machines required to produce it, materials, tolerances, etc.

At the same time, the systems which are the "blades" of the propeller must have characteristics built into them which

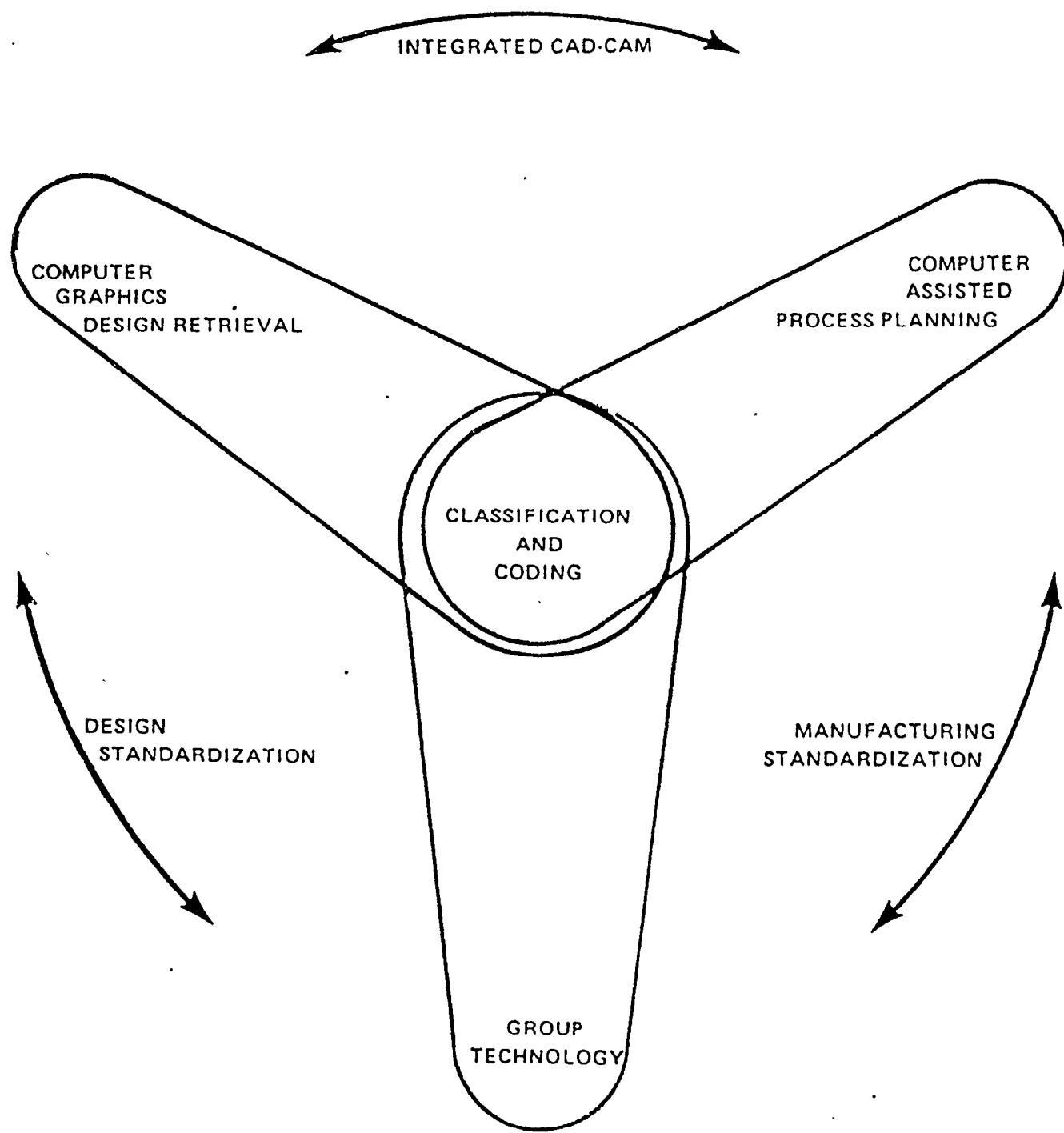


FIGURE 1



will make it possible for them to use this information and integrate into their own tasks. All of the systems must talk in a common language and about the same kinds of things.

This is the philosophy behind the development of the MI CLASS coding and classification system and its related systems, notably MIPLAN for computer assisted process planning, MI GRAPHICS for computer graphics, and MI GROUP for Group Technology.

Each of these systems can stand alone. All are integrated, however, so that they can utilize a common database and interrelate with each other.

For example, a computer graphics operator using the MI GRAPHICS system can begin by coding the part to be designed from a rough sketch. The resulting code number provides the designer with an access to the database. If the part, or a similar part has been designed in the past, the existing drawing can be retrieved on the designers graphics screen and, if necessary, modified. This obviously reduces the possibility of design proliferation. If Group Technology analysis has been used in the refinement of the database, then it is also likely that the design which appears on the screen will be one which can be produced most efficiently and at the lowest cost for the company.

Using the MIPLAN computer assisted process planning system, the process planner can also begin with a rough sketch and code the part. If the same part or similar parts have been produced in the past, that information will be immediately accessible through the code number. If Group Technology has been utilized, the process plan retrieved by the system will be the optimal one to produce the part - again reflecting the company's manufacturing capabilities and operating idiosyncrasies.

The information generated as each of these three systems are used increases the data available to everyone in the design and manufacturing areas. Because all of the systems are intergrated the pipeline is expanded in its diameter and more fluid - or in this case production' - can flow through the same operation in the same time.

It is this integration and cross-communication among systems which will make the promise of productivity through computerization a reality for batch manufacturing. In the years to come, new blades will be added to the propeller and the pipe will grow even wider.

## PRODUCTIVITY: MANAGEMENT'S BONUS (!!!) OR FAILURE (???)

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Dickinson, Texas

### ABSTRACT

Overall responsibility for productivity accrues to management--or lack of it. Productivity starts with planning and ends with timely deliveries. Its objectives are satisfied customers and the achievement of profit goals. Thus productivity in its broad sense, means a lot more than just meeting engineered time standards of output throughout the manufacturing cycle.

Some reasons given as managerial weaknesses underlying the productivity problem are: (1) failure to develop adequate planning in advance for the production cycle; (2) inability to accurately and fairly measure productivity throughout the cycle; (3) failure to control the production cycle even where measurement techniques have been implemented; and (4) inattentiveness to legitimate complaints, or recommendations, advanced by employees.

Three major areas of economic benefits to a shipyard are discussed.

## PRODUCTIVITY, MANAGEMENT' S BONUS (!!!) OR FAILURE (???)

Webster's dictionary defines productivity as:

- 1) the quality or state of being productive, or
- 2) the rate of production.

To the Industrial Engineer, productivity means:

the rate (%) of performance while engaged in useful productive work, multiplied by the rate (%) of utilization, or the time actually engaged in productive activity.

Example - 80% (performance) X 80% (utilization)  
= only 64% productivity

But to us laymen responsible for achieving Productivity -

It means simply:

Getting the most, out of the least, at the lowest possible cost without sacrificing quality, or safety, in order to optimize the return or profit, on the shareholder's investment.

And we all know what it takes to do it:

Good management  
Up-to-date methods, processes, systems and procedures (Tools)  
And, modern control techniques that are used to take action, or steer the company's operations toward achievement of pre-planned objectives.

While this symposium is directly related to the Shipbuilding Industry, the topic to be discussed - Productivity - is a universal problem to be found in any industry.

Overall responsibility for productivity accrues to management - or lack of it. Productivity starts with planning and ends with timely deliveries. Its objectives are satisfied customers and the achievement of profit goals. Thus productivity in its broad sense, means a lot more than just meeting engineered time standards of output throughout the manufacturing cycle.

These are some of the reasons which we, as consultants striving to improve productivity, have found to be managerial weaknesses underlying the productivity problem:

- o Failure to develop adequate planning in advance for the production cycle. Questions relative to capacity, time, profitability, etc., should be confronted and finalized.
- o Inability to accurately and fairly measure productivity throughout the cycle.
- o Failure to control the production cycle even where measurement techniques have been implemented. In many instances, management hesitates to exert its rights under the fear that labor problems might be created and jeopardize their personal situation. Example - shutdown due to walk-out.
- o Inattentiveness to legitimate complaints, or recommendations, advanced by employees. This leads to destroying the credibility of the system, or failure to capitalize on changes which could lead to improvement.

Some statistics on productivity in the USA: We were the most productive nation in the world in the 50's and 60's with productivity equal to our annual 3.2% rate of growth. Output per employee hour grew at a 1% rate during the seventies and is now level or losing ground mainly due to inflation.

The approaches being undertaken to increase productivity are predominantly related to the workers. When one hears the term worker, the tendency is to think in terms of the blue-collar worker. Yet today, the white-collar worker probably represents an area for equal or even greater concern. I say this because steps have been taken over the years to establish control over operations related to the blue-collar workers. Very little has been done to control the productivity of white-collar workers - and they have become a growing breed over the last 20-30 years.

From my experience and also what you have heard these last three days the blue-collar worker will produce when given the plans, materials and a good working atmosphere.

In other cases, machines set the pace for blue-collar workers. What sets the pace for the white-collar worker?

How many of you in attendance have experienced problems with your Engineering Department, i.e., estimates, drawings, bills of material, etc. Yet their productivity can be controlled through the implementation of similar techniques - planning, scheduling and control.

Management is becoming aware of the need to involve the white-collar worker into the many productivity programs that are and have been initiated.

A quick review of some of the AMA management briefing reports, research studies, books and magazine articles listed below indicate the emphasis and the number of people that are attacking the problem of productivity.

"Quality Circles" A Team Approach to Problem Solving

"Productivity The Human Side"

"Idea Management: How to Motivate Creativity and Innovation"

"Gainsharing Involvement, Incentives, and Productivity"

"Key to Enhancing System Development Productivity"

"Going From A to Z -- Thirteen Steps to a Theory Z Organization"

In addition one only has to look at what you will hear by attending a one day seminar on productivity:

- o How to Apply the "Quality Circle" concept to your company.
- o How to measure employee work performance.
- o How you can implement a positive reinforcement permission system.
- o How to develop an accurate feedback system.
- o How to determine the types of employee involvement techniques which are most likely to prove successful in your own company . . . based on real experiences of other companies in the U.S. and overseas.
- o How to keep your own productivity improvement program rolling by identifying and overcoming the potential problems.

After all this I still must agree with the approach being taken relative to the white and blue-collar workers learning the theory of productivity and communications but the results if successful, of all these programs will probably show as a very small gain in output per hour or yearly growth rate. Dr. Tweeddale's pie charts show that technology is the biggest part of the pie.

From our experience, we have found that significant economic benefits (productivity) to a shipyard can be broken down into three major areas:

1. Scheduling, Planning and Production Control (PPC).
2. Operating methods, procedures, and new equipment.
3. Facility modifications.

Improvements in the range of 30%, 50%, 90%, yes, even 1000% can be realized in less than a year or two.

Item 3 will not be discussed in this paper based on the high cost of money and our recent experience. This experience shows that you can invest a lot of capital in facility modifications but if you don't have an effective PPC system very little productivity improvement will take place. The implementation of items 1 and 2 will be significantly less expensive and can be initiated in a much shorter period of time and also offers the best return on investment (ROI).



### Item 1 Scheduling, Planning and Production Control

For many years, management has recognized the significant benefits to be derived from a soundly developed and closely monitored system of Scheduling, Planning and Production Control (PPC). Over the more recent years the concept of Materials Management has been adopted by progressively managed companies to emphasize the need for executing approved planning and meeting desired objectives. Materials Management is an integral part of a good PPC system. On the next page we have listed the major elements of a practical PPC system.

## Planning and Production Control (PPC)

An independent planning and production control group working with and reporting to the Chief Operating Officer.

A master strategic plan and an integration of schedules for construction, engineering and procurement very early in each contract.

Creation of small budget, short span work orders manageable by a foreman.

Clarification of production management's role at each level -

- work orders at the foreman level

- area control by Superintendents

- ship completion for the Production Manager

- multi-plant integration by VP of Operations

Manload forecasting and progressing summarized from work order budgets and schedules.

Material requirements correlated to individual work orders and based on an accurate bill of material from Engineering.

A dedication by line Managers of each functional group to progress their departmental efforts to the integrated schedules, and notify follow-on departments of pending delays before they happen.

### Explanation of Planning Viewgraphs

On the next three viewgraphs we show a good example of the Productivity Bonuses attained through good innovated planning:

At the start this deck barge was erected using assembled units as shown for the midbody (A through D). The rakes were erected as units #1, #2, #3, #12, and #13. The erection sequence for the midbody units were as follows:

- o Units A for Modules #5, #7, #9, and #11
- o Units B for Modules #5, #7, #9, and #11
- o Units C for Modules #5, #7, #9, and #11
- o Units D for Modules #5, #7, #9, and #11
- o Barge moved one half breadth
- o Sequence repeated for Modules #4, #6, #8, and #10

This method of erection resulted in a time span of 6 weeks from keel to launch and the erection of 76 midbody units.

Subsequent new erection sequences were planned and implemented. The first plan (B) was to assemble the trusses and bulkheads with the stiffened bottom panels prior to erection. This resulted in a one week reduction in duration time and a 5% improvement in production manhours. A 16.6% improvement was attained in time related manhours i.e.: Supervision, QC, cleaners, temporary lights and ventilation, crane operators, etc.

The next plan (C) was to assemble the deck assembly prior to erection. Similar, but not quite as good improvements were attained. The next plan (D) assembled the side units to the module prior to erection. All staging, cleaning and testing (where possible) was accomplished prior to erection. Most here are probably doing this but as Niel Spillane explained this morning, the majority of the small and medium yards are not aware of these techniques. Viewgraph #2 summarizes improvements and lists the present market place data for a barge this size. Viewgraph #3 summarizes the improvements with the bottom line being a 225% yearly growth rate - That's productivity.

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PROJECT I REAPS

SUBJECT PRODUCTIVITY

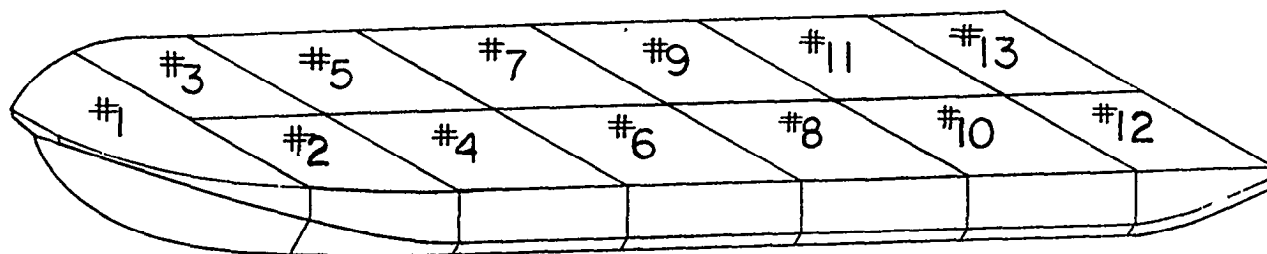
BONUSES THROUGH  
PLANNING & SYSTEMS

BYML DATE 9 8-81

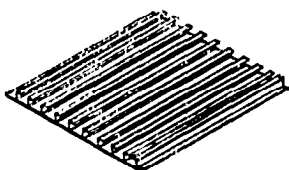
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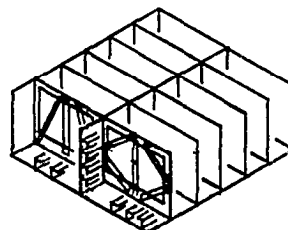
SHEET NO! OF 3



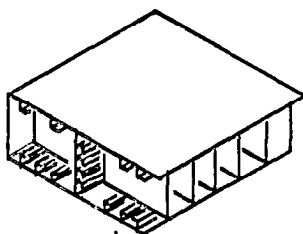
260'x72'x15' DECK CARGO BARGE



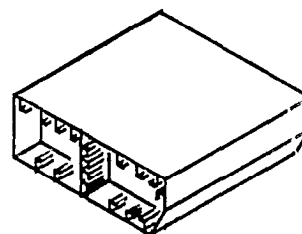
"A"  
BTM. R & STIFFR'S.



"B"  
TRUSSES & BHDS



"C"  
DECK R



"D"  
SIDES  
COMPLETE  
HALF BREADTH MODULE

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## SUMMARY TABLE

ITEMS	<u>ERECTION METHOD</u>				
	A	B	C	D	A vs D
NUMBER OF MIDBODY ERECTION ASSEMBLIES	76	24.	16	8	68 LESS
IMPROVEMENT IN PRODUCTION MANHOURS	0	5%	2%	10%	17%
IMPROVEMENT IN TIME RELATED MANHOURS	0	16.6%	16.6%	16.6%	50%
KEEL TO LAUNCH TIME IN WEEKS	6	5	4	3	3 LESS

## LARGE DECK BARGE 260' X 72' X 15'

SELLING PRICE : \$1,500,000 - % PROFIT: 15% - SALES PROFIT: \$225,000

MANHOURS 35,000 (PRODUCTION 24,500 TIME RELATED 10,500)

HOURLY RATE: 15 SHIPYARD CAPACITY = 8 BARGES PER YEAR

## MIDBODY ERECTION UNITS

BOTTOMS	8
BULKHEADS	12
TRUSSES	40
DECKS	8
SIDES	8
TOTAL	76

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## SUMMARY OF IMPROVEMENTS

ADDITIONAL SALES' PROFIT \$ I, 800, 000  
 ( 8 - BARGES x \$225, 000 SALES PROFIT=

PRODUCTION SAVINGS = \$ 999, 000  
 (24, 500 HOURS x 17% x \$15 x 16 BARGE)

TIME RELATED SAVINGS = \$ I, 260, 003  
 (10, 500 HOURS x 50% x \$15~ 16 BARGES)

TOTAL ADDITIONAL PROFIT \$4, 059, 600

\$ 4, 059, 600  
\$ 1, 800, 000 = 225% GROWTH

THIS IS PRODUCTIVITY

## Item 2. Operating Methods, Procedures and New Equipment

Significant productivity improvements can be obtained through the use of new innovative production methods, operating procedures and the purchase of new labor saving and greater capacity equipment. Most of you have seen the great advances made in shipbuilding through the use of computers, numerical controlled burning and marking, semi and automatic welding, preout fitting, etc.

Another area that has been modernized in many of our blue water shipyards is panel assembly and stiffening. Some of the Inland Waterways, Great Lakes, and Coastal Boat and Barge yards have also improved this operation, but many have not. The next five (5) view graphs indicate three different methods and compare the advantages of each. Let me review the three methods and you can judge for yourselves what course of action today's shipyard managers should take to obtain productivity.

Method A is used by most small and medium size shipyards since they do not have the throughput requirements to justify a good ROI necessary to purchase the equipment used in Method B.

Method B or a panel line similar to the ESAB or Wenzlaff line is common in most yards that have modernized over the last 10 to 15 years. Another version would be the Ogden plate stiffener "pull through" machine and a panel welder to weld stiffened plates together.



I have just recently developed the Method C concept, the equipment is being manufactured by Ogden Engineering, Inc., and will be installed in a new barge yard being built for Bergeron Barges, Inc., with operations scheduled to start in February, 1982.

This panel stiffening line, Method C, as you can see from the last two slides offers tremendous advantages not only in manhours saved but in capacity, materials handling, hiring, production floor space etc.

This is the type of PRODUCTIVITY we all should be investigating and implementing.

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S BONUSES THROUGH  
PLANNING G & SYSTEMS SHEET NO OF 5

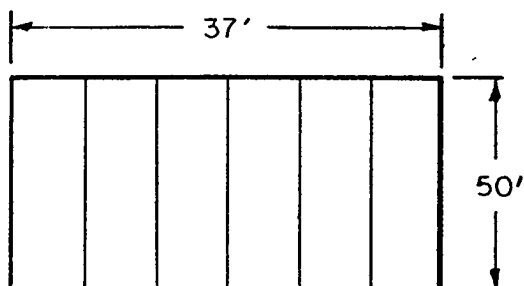
## **(A) PANEL AND PANEL STIFFENING ASSEMBLY**

SIZE = 37' x 50'

MANHOURS = 100 PER PANEL

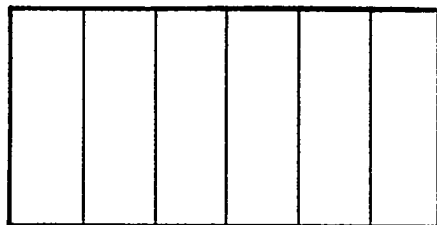
TIME = 4 SHIFTS (32 HOURS)

STEP 1



LAYDOWN, LAYOUT  
TACK-WELD AND  
MANUAL WELD 5 BUTTS

STEP 2



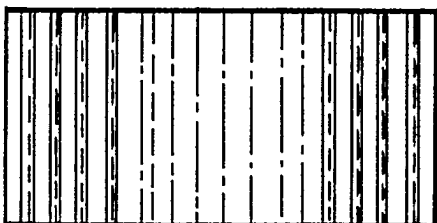
TURN OVER, MANUAL WELD  
2ND SIDE. LAYOUT, SQUARE  
PANEL AND TRIM

STEP 3



LAYOUT FOR 18 STIFFENERS.  
LOCATE AND TACK -WELD  
STIFFENERS.

STEP 4



MANUALLY STITCH- WELD 18  
STIFFENERS. INSPECTION  
AND PICK-UP. REMOVE PANEL.

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BONUSES THROUGH  
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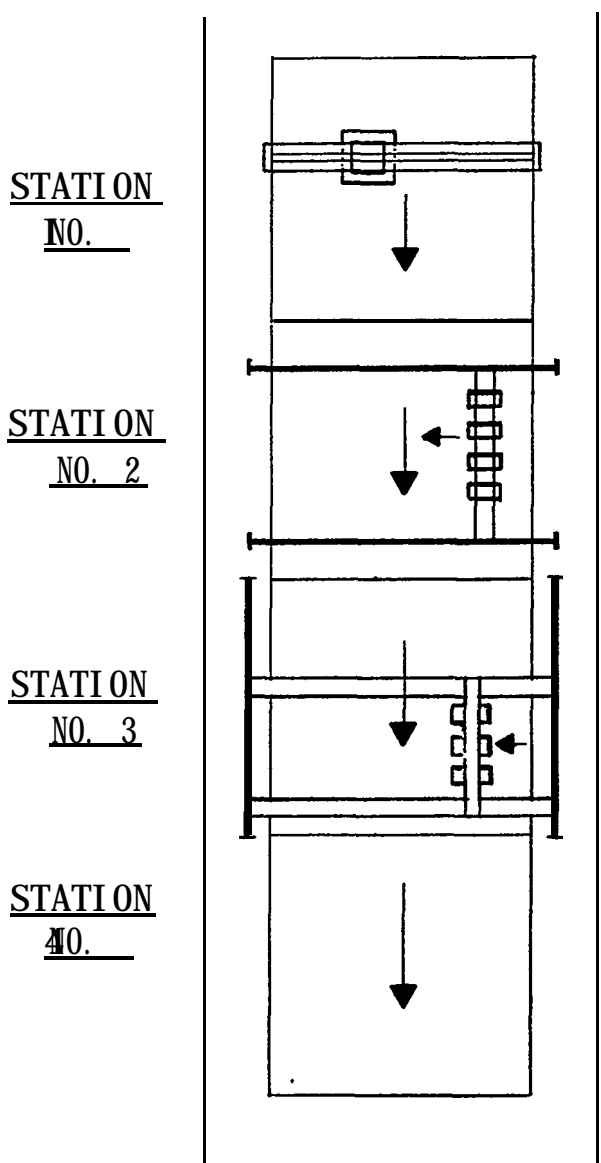
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SHEET NO2 OF 5

**(B) PANEL AND PANEL STIFFENING ASSEMBLY**

SIZE- = 37' x 50'

MANHOURS = 60 PER PANEL

TIME = 1/2 SHIFT (4 HOURS)



ONE- SIDED PANEL WELDING  
USING FIXED GANTRY WITH  
TRACTOR AND MAGNET BED.

CONVEYOR SYSTEM BETWEEN  
STATIONS.

FOUR MODULE CLAMPING MACHINE  
LOCATES STIFFENERS, CLAMPS  
AND TACK-WELDS.

THREE MODULE WELDING MACHINE  
(6' HEADS). SUB-ARC FILLET  
WELDING (STITCH) OF STIFFENERS.

INSPECTION AND PICK -UP.

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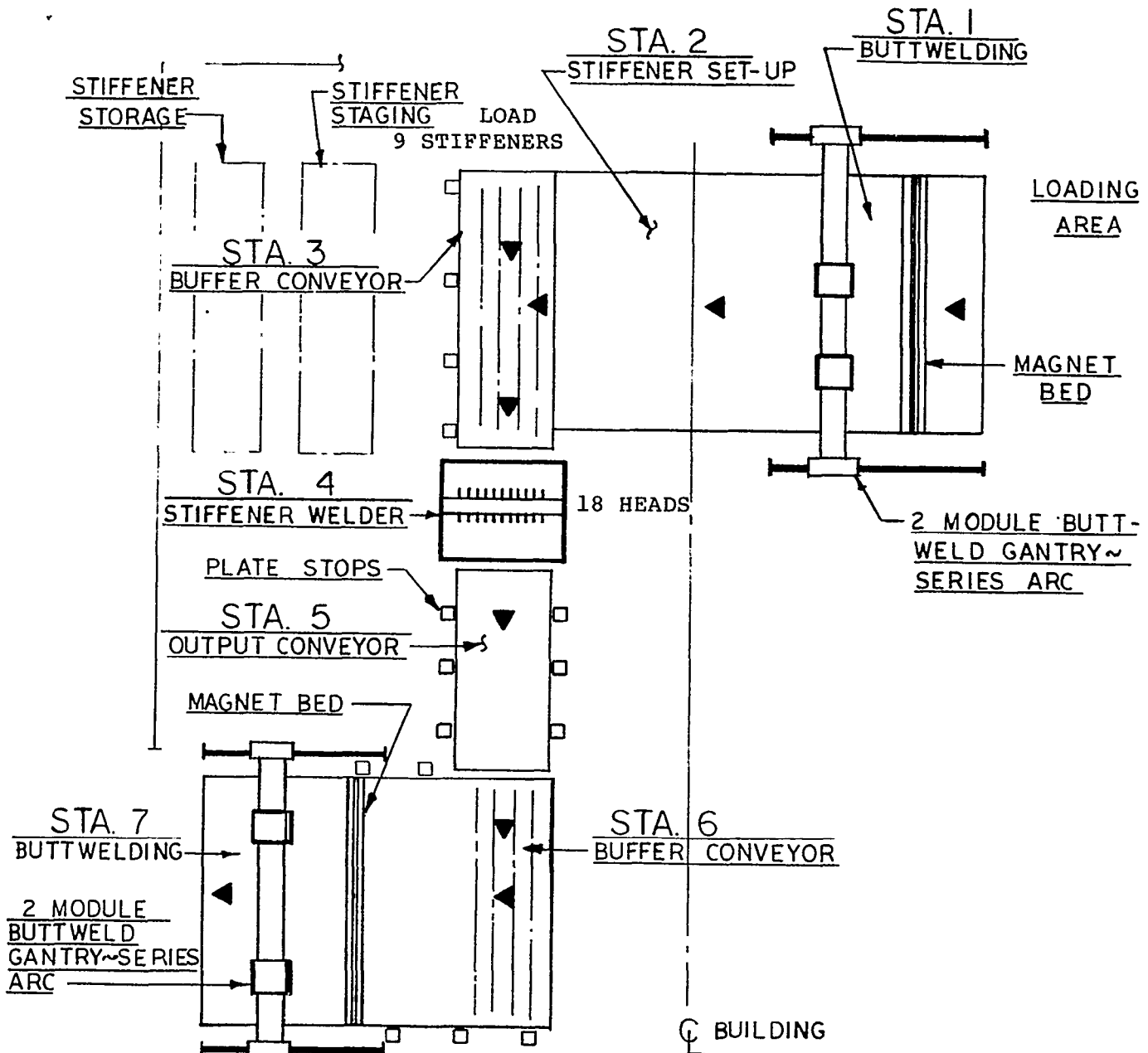
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## ⑨ PANEL AND PANEL STIFFENING ASSEMBLY

SIZE = 37' X 5G'

MANHOURS= 12 PER PANEL

TIME = 48 MINUTES



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PLANNING & SYSTEMS SHEET NO4 OF 5

## SUMMARY TABLES

ITEMS	<u>ASSEMBLY METHOD</u>					
	A	B	C	A vs. C	B vs C	
NUMBER OF PANELS PER, SHIFT	1/4	2	10	93/4		8
MANHOURS PER PANEL	100	60	12	88		48
WORKING AREA (SQ. FT)	300	2000	2000	(1700)		0

## EQUIVALENTS TO EQUAL C's CAPACITY

(ONE WEEK, 10 SHIFTS = 100 PANELS)

	<u>C</u>	<u>A</u> (VARIANCE)	<u>B</u> (VARIANCE)
NUMBER OF MANHOURS/MEN	1200/15	10,000/125 (8800/110)	6000/75 (4800/60)
WORKING AREA (SQ. FT.)	200,000	1,200,000 (1,000,000)	1,000,000 (800,000)
x TIME	(100 x 2000)	(100x300x10/25)	(100 x 2000 x 10/2)

## SUMMARY OF IMPROVEMENTS

	<u>A</u>	<u>B</u>
MAN HOURS PER WEEK	8800	4800
(x \$15. RATE)	\$132,000	\$72,000
MANHOURS PER YEAR	444000	240,000
(50 WEEKS x \$15. RATE)	\$6,600,000	\$3,600,000
<del>(A OR B/C)</del> % GROWTH	733 %	400 %

IN ADDITION:

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PLANNING & SYSTEMS      JOB NO.                       
   SHEET NO5 OF 5

## OTHER MAJOR SAVINGS

1. THE MEN SAVED IN ASSEMBLY PER SHIFT 75 (B) OR 110 (A), CAN BE TRANSFERED TO ERECTION TO REDUCE THE DURATION AND LEAD TO ADDITIONAL SALES PROFIT AND MANHOUR SAVINGS ON THESE ADDITIONAL SALES.
2. ASSUMING ADDITIONAL SALES, A COST AVOIDANCE WILL RESULT SINCE AN ADDITIONAL FACILITY OF 800,000 SQ. FT. (B) OR 1,000,000 SQ. FT. (A) WILL NOT BE REQUIRED.

## RESULTS

- MANHOUR SAVINGS
- ADDITIONAL SALES PROFIT
- ADDITIONAL SALES PROFIT MANHOUR SAVINGS
- MANPOWER MADE AVAILABLE TO INCREASE THROUGH PUT
- FACILITY COST AVOIDANCE

THIS IS PRODUCTIVITY

I would like to close this paper with a commentary prepared for the Houston Business Journal by Richard Jacob of the firm of Harris Management Technology:

"In the past several years, much activity and thought has been generated in the area of increasing productivity.

Many theories have evolved, sprung-up and been generated as to how this should be done. One extremely workable method, in use for at least 20 years, is the method of managing personnel based on a system of statistics reflecting their actual production. The method revolves around a very simple, but often overlooked law: If you reward non-production you get non-production.

Conversely, this law becomes: If you reward up-production you get more production.

And finally: When you penalize production, you get non-production.

These laws can be observed most directly in a welfare state in which non-production is rewarded at the expense of producers. It may seem very obvious, but it is a point which must have been overlooked by most 20th century governments. Another example would be the current system of income tax in this country. The more a person produces and earns, the more heavily he is taxed (penalized).

What this boils down to is this:

1. Every person in an organization is working to produce something. This something usually adds up to a product or service which can be exchanged with other activities in return for support. The support usually adds up to food, clothing, shelter, money, tolerances, and cooperation (good will).

2. This product or service can be quantified and placed on a graph in relation to time. For example: An automobile salesman's statistic could be "number of dollars in commissions earned." This would accurately reflect his actual production. He would then plot this figure on a week-to-week or month-to-month basis.

3. After a few weeks or months, the graph will show the relative rises and falls in his actual production. A graph going steadily down indicates at a glance, "this person is in trouble." A graph going steadily up shows, "this, person is productive."

4. Management then seeks to reinforce, by whatever means is successful, the productive personnel, based on their actual statistics. Personnel in trouble could be handled, or if warranted, terminated.



Sounds too simple? Well, there is certainly a lot more to this method of increasing productivity than the above, but it allows for proper evaluation, commendation or reprimanding, and promotion or demotion, all based on actual production, not personality or rumor or whatever else can come into play.

So specialize in production and everybody wins.. Reward it, and may your company never be the same again. "

Management has failed if productivity doesn't increase to meet satisfactory profitability levels.

Management's Bonuses are in their own deeds and actions and are unlimited.

U. S. SHIPBUILDING STANDARDS PROGRAM  
LONG-RANGE PLAN

Yoshinori Ichinose  
Vice President  
IHI Marine Technology Inc  
New York, New York

ABSTRACT

Ishikawajima-Harima Heavy Industries/IHI-Marine Technology is developing a long-range plan for the U. S. shipbuilding standards program under a sub-contract with Bath Iron Works Corporation acting in its capacity as manager of the Ship Producibility Program.

Primary emphasis of the long-range plan is directed at near term (2 to 3 year) priorities to achieve maximum benefits at both industry and individual shipyards levels. Secondary emphasis is aimed at developing midterm (5 to 7 year) and long-term (10 to 20 year) goals to serve as planning guidelines for ongoing efforts.

The basic goals and objectives of the U. S. shipbuilding standards program long-range plan are summarized. Included are such examples as the need to reduce design and engineering cycle time costs, the need to shorten manufacturing lead times for critical materials, and the desirability of implementing outfit unit construction and accuracy control concepts. The recommended organizational infrastructure for standards development is addressed, and appropriate divisions of responsibility among ASTM Committee F-25 on standards, SNAME Panel SP-6 on standards and specifications, the government, shipbuilders, regulatory agencies, supporting industries and other concerned parties are discussed.

TASK S-29 U.S. SHIPBUILDING STANDARDS LONG-RANGE PLAN

1. TASK OBJECTIVE

- A. PROVIDE GUIDELINE FOR THE U.S. SHIPBUILDING INDUSTRY TO ESTABLISH THEIR SHIPBUILDING STANDARDS LONG-RANGE DEVELOPMENT PLAN, BASED UPON THE KNOWLEDGE AND EXPERIENCE OF THE JAPANESE SHIPBUILDING INDUSTRY ON STANDARDIZATION
- B. DIRECT PRIMARY EMPHASIS AT SHORT-TERM(2-3) YEARS) PRIORITY GOALS TO ACHIEVE MAXIMUM BENEFITS AT BOTH INDUSTRY AND INDIVIDUAL COMPANY LEVELS.
- C. PLACE SECONDARY EMPHASIS ON DEVELOPMENT OF MID-TERM (5-7) YEARS) AND LONG-TERM (10-20 YEARS) GOALS TO SERVE AS PLANNING GUIDLINES FOR ONGOING EFFORTS.

2. APPROACH

- A. CONDUCT A BACKGROUND SURVEY OF THE SHIPBUILDING INDUSTRY TO INVESTGATE THEIR NEEDS FOR STANDARDIZATION, AND THE STATUS-QUO OF STANDARDIZATION EFFORTS IN U. S. A.
- B. CATEGORIZE STANDARDS BY THEIR INFLUENCE TO THE INDUSTRY (I. E. , NATIONAL, INDUSTRY, COMPANY LEVELS) AND BY THEIR FUNCTIONS (I. E. , PRODUCTS, DESIGN/ENGINEERING, PERFORMANCE, TESTING/INSPECTION, PRODUCTION, ACCURACY STANDARDS).
- C. ORGANIZE AND CATEGORIZE STANDARDS ITEMS IN A FORM OF A "TREE STRUCTURE".
- D. SELECT AND PRIORITIZE STANDARDS ITEMS FROM THE "TREE STRUCTURE, AND CLASSIFY INTO SHORT-TERM, MID-TERM, LONG-TERM GOALS.
- E. PROVIDE GUIDELINES. FOR- RESPONSIBLE ORGANIZATIONAL STRUCTURES TO DEVELOP AND IMPLEMENT STANDARDS, CODING, ETC.

3.

**STANDARDS CATEGORIES BY PREDOMINATE LEVELS**

**NATIONAL STANDARDS**

STANDARDS ENFORCED By GOVERNMENT RULES/REGULATIONS.

**FEATURES:**

STANDARDS INTERRELATED TO INTERNATIONAL STANDARDS, RULES/REGULATIONS (ISO, IMCO, IACS, ETC.) AND/OR FEDERAL REGULATIONS (USCG, USN, ETC.)

**EXAMPLES :**

UNITS, CODES, LIFE SAVING EQUIPMENTS, FIRE APPLIANCES, ANCHORS, VALVES, ETC.

**INDUSTRY-WIDE VOLUNTARY STANDARDS**

STANDARDS ESTABLISHED BY PRIVATE ORGANIZATIONS ACCEPTED BY THE INDUSTRY (ASTM, SNAME, IEEE, ETC.)

**FEATURES:**

STANDARDS USED NATION-WIDE BY THE INDUSTRY AS CRITERIA OR YARDSTICKS,

**EXAMPLES:**

DESIGN CRITERIA/SPECIFICATIONS, FITTINGS, EQUIPMENT, QUALITY, TESTING/INSPECTION, PERFORMANCE.

**COMPANY IN-HOUSE STANDARDS**

STANDARDS ESTABLISHED BY INDIVIDUAL COMPANIES.

**FEATURES:**

STANDARDS TO MEET COMPANY'S PECULIAR REQUIREMENTS.

**EXAMPLES:**

DESIGN/ENGINEERING, PRODUCTION, TESTING/INSPECTION, MATERIALS, MODULES, MANUALS, ETC.

4. CATEGORIZATION BY FUNCTIONS

PRODUCTS STANDARDS

BASIC FITTINGS, EQUIPMENTS, ETC. ,  
COMMONLY USED IN SHIP'S SYSTEMS.

EXAMPLES:

ANCHORS, BITTS, DOORS, PIPE JOINTS  
LIGHTING FIXTURES, ETC.

DESIGN/ENGINEERING  
STANDARDS

DESIGN' CRITERIA, SPECIFICATIONS,  
ETC. , FOR SHIP'S SYSTEMS.

EXAMPLES:

STANDARD SPECIFICATIONS, CALCUL-  
ATION FORMS, . ANALYSIS METHODS, ETC.

FUNTIONAL PERFORMANCE  
STANDARDS

STANDARD SPECS FOR MACHINERY AND  
EQUIPMENT, MATERIALS, COMPONENTS.

EXAMPLES:

STANDARD PERFORMANCE SPECS FOR  
LIFE BOATS, NAVIGATION EQUIPMENTS,  
PUMPS, GENERATORS, SWITCHBOARDS,  
VALVES, PAINTS, ETC.

TESTING/INSPECTION  
STANDARDS

TESTING/INSPECTION PROCESSES,  
ACCEPTANCE LEVELS, ETC.

EXAMPLES:

STANDARD PROTOCOLS OF SEA TRIALS,  
SYSTEMS, STANDARDS FOR SURFACE  
TREATMENT AND PAINTING, ETC.

PRODUCTION PROCESS  
STANDARDS

CONSTRUCTION METHODS, OUTFITTING  
METHODS, WELDING PROCESSES, ETC.

EXAMPLES:

STANDARD PROCESSES FOR HULL CON-  
STRUCTION, PIPE FABRICATION, SHAFT  
ALIGNMENT, ETC.

ACCURACY/TOLERANCE  
STANDARDS

ACCEPTANCE LEVEL OF ACCURACY  
TOLERANCE IN PRODUCTION.

EXAMPLES:

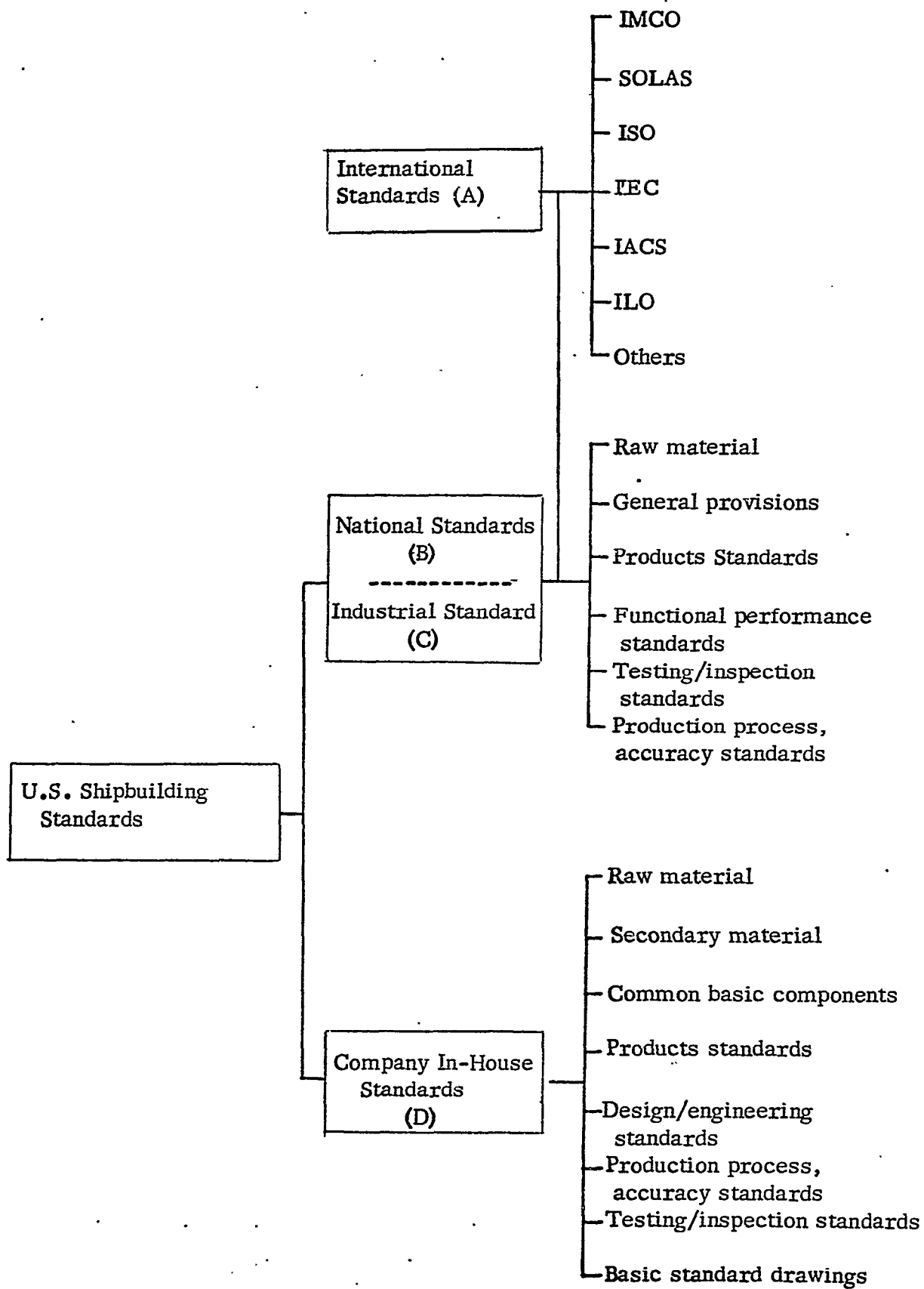
ACCURACY OF HULL STRUCTURE, PIPE  
JOINTS, SHAFT ALIGNMENT, ETC.

5. STANDARDS TREE STRUCTURE

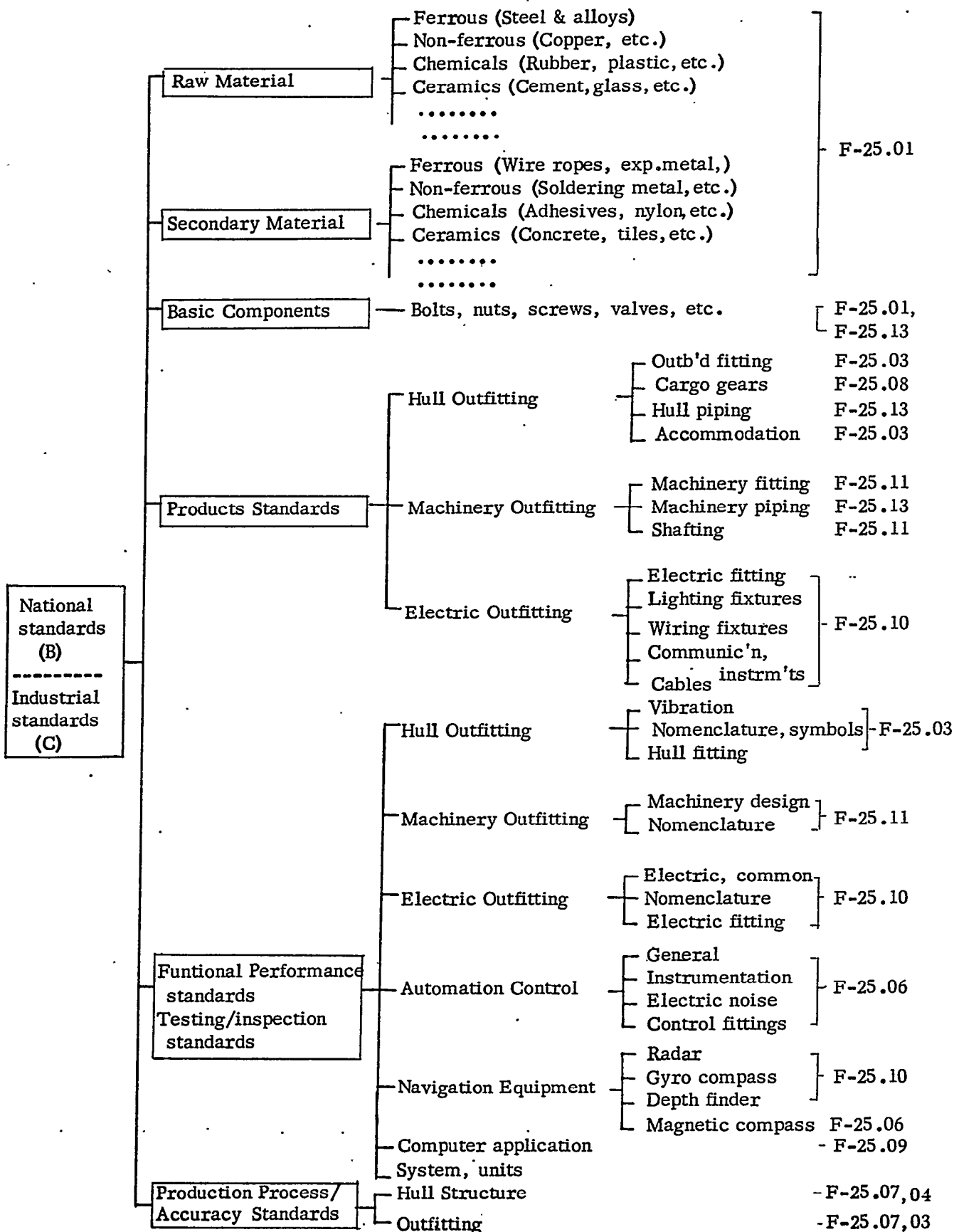
PURPOSE: TO ORGANIZE AND SYSTEMATIZE ALL STANDARDS ITEMS, AND CLASSIFY THEM INTO STANDARDS CATEGORIES IN A FORM OF A TREE STRUCTURE TO IDENTIFY THE FAMILY GROUP THEY' BELONG TO.

FORMAT: AT EACH STANDARDS LEVEL (NATIONAL, INDUSTRY, COMPANY LEVELS); CLASSIFY STANDARDS ITEMS INTO FUNCTIONAL GROUPS (PRODUCTS, DESIGN/ENGINEERING, ETC.) AND THEN INTO SYSTEMS OR WORK PROCESSES (HULL STRUCTURE, HULL OUT-FITTING, ETC.), AND FINALLY INTO INDIVIDUAL ITEMS.

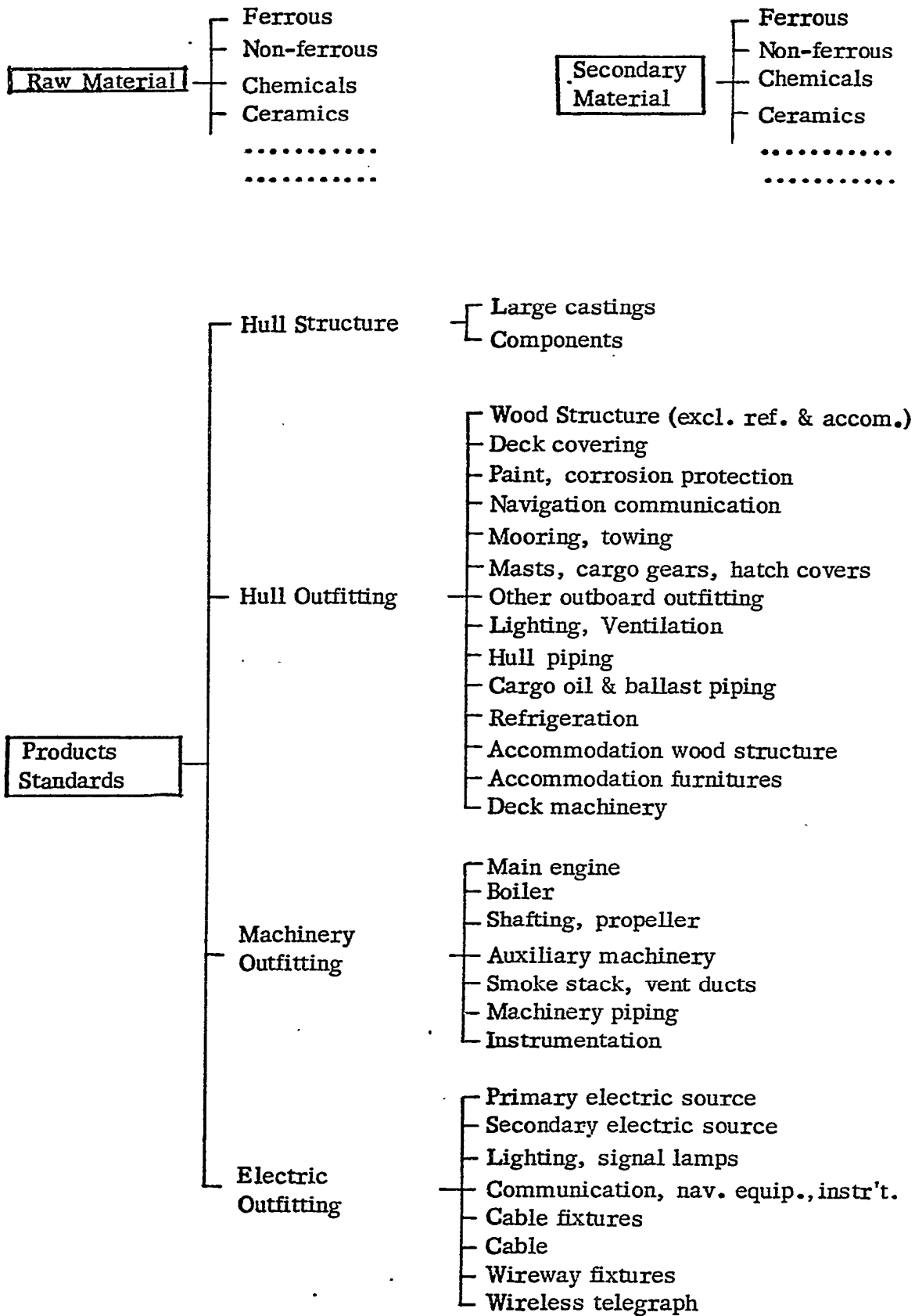
# EXAMPLE OF TREE STRUCTURE



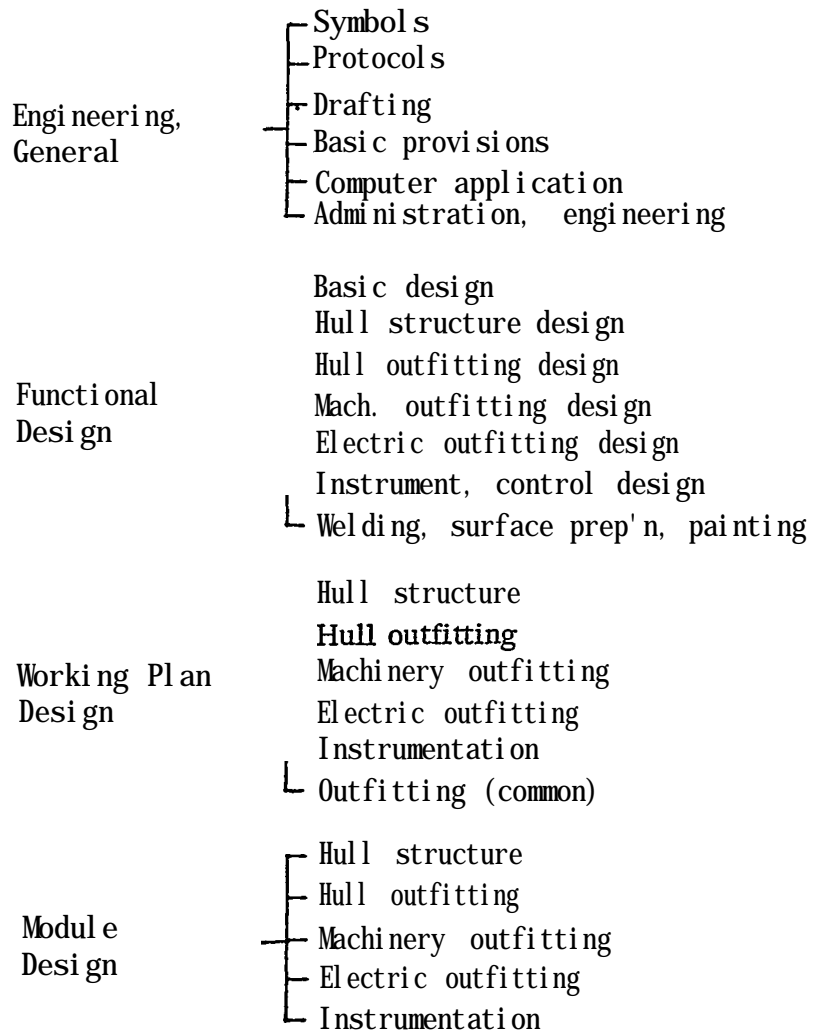
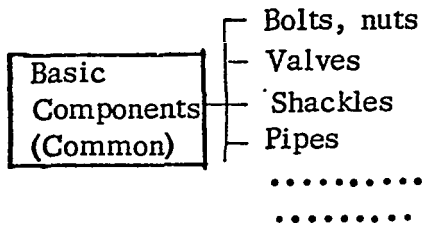




Company In-House Standards (D)



# Company In-House Standards (D)



Design/ Engineering Standards
-------------------------------------

## 6. STANDARDIZATION GOALS

### SHORT-TERM GOALS (2-3 YRS):

PRODUCTS STANDARDS

FUNCTIONAL PERFORMANCE STANDARDS

DESIGN/ENGINEERING STANDARDS (BASIC).

### MID-TERM GOALS (5-7 YRS):

DESIGN/ENGINEERING STANDARDS (LONGER TERM)

TESTING/INSPECTION STANDARDS (BASIC)

PRODUCTION PROCESS STANDARDS (BASIC)

### LONG-TERM GOALS (10-20 YRS):

DESIGN/ENGINEERING STANDARDS (LONGER TERM)

TESTING/INSPECTION STANDARDS (LONGER TERM)

PRODUCTION PROCESS STANDARDS (LONGER TERM)

ACCURACY/TOLERANCE STANDARDS

( 1-25 )

<u>Type of Standards</u>	<u>Major Users</u>	<u>Benefits</u>	<u>Circumstances</u>	<u>Development Time</u>	<u>Priority</u>
Product Standards	Shipyard Vendor Regulatory Bodies	Design Purchasing Inspection	Can be developed independently	Short	Short-term
Functional Performance Standards	Shipyard Vendor Regulatory Bodies	Design Purchasing Inspection	Can be developed independently	Short	Short-term
Design/Engineering Standards	Shipyard	Design Production	Should be based on proven standardized products	Need time to coordinate within industry or company	Short-term & Mid-term
Testing/Inspection Standards	Shipyard, Vendor, Shipowner Regulatory Bodies	Inspection Production	No restrains	Need time for coordination with the groups concerned	Mid-term & Long-term
Production Process Standards Accuracy Standards	Shipyard Shipowner Regulatory Bodies	Production Inspection	Will be enhanced if products/functional/design standards, etc. are established	Need time for coordination with the groups concerned	Mid-term & Long-term

## 7. ORGANIZATIONAL FOR STANDARDIZATION.

OBJECTIVE: TO DEFINE RESPONSIBILITIES AT EACH LEVEL FOR STANDARDS PLANNING, DEVELOPMENT, IMPLEMENTATION AND FOLLOW-UP.

### FUNCTIONS REQUIRED:

- PLANNING & DETERMINATION OF LONG-RANGE PLAN
- DEVELOPMENT OF STANDARDS
- APPROVAL AND ENACTMENT OF STANDARDS
- PUBLICATION OF STANDARDS
- FOLLOW-UP & MAINTENANCE OF STANDARDS

### BASIC TASK GROUP STRUCTURE:

- STANDARDS COMMITTEE: DETERMINE LONG-RANGE AND ANNUAL DEVELOPMENT PLANS, APPROVE FINAL DRAFT STANDARDS.
- DIVISIONAL COMMITTEES: ORGANIZED UNDER STANDARDS COMMITTEE BY FUNCTIONS TO DRAFT LONG-RANGE & ANNUAL DEVELOPMENT PLANS, EVALUATE DRAFT STANDARDS DRAFTED BY WORKING COMMITTEES.
- WORKING COMMITTEES: ORGANIZED UNDER EACH DIVISIONAL COMMITTEE TO DRAFT STANDARDS.

8. RECOMMENDED U. S. SHIPBUILDING STANDARDS LONG-RANGE PLAN

A. FINAL REPORT: FORMAT

VOLUME I: - EXECUTIVE SUMMARY  
BACKGROUND CONSIDERATIONS &  
GUIDELINES FOR STANDARDIZATION.

APPENDICES: - BACKGROUND SURVEY RESULTS.  
JAPANESE APPROACH TO STANDARD-  
IZATION IN SHIPBUILDING.

VOLUME II: - RECOMMENDED U. S. SHIPBUILDING  
STANDARDS LONG-RANGE PLAN.  
GUIDELINES FOR SELECTION AND  
ASSESSMENT OF STANDARDS.  
GUIDELINES FOR CODING AND COM-  
PUTER APPLICATION.

APPENDICES: - STANDARDS TREE STRUCTURE.  
LIST OF STANDARDS ITEMS CATEG-  
ORIZED BY PRIORITY ORDERS.  
STANDARDS PUBLICATION FORMAT  
EXAMPLE OF SYSTEM CODES

VOLUME III: - CATALOGUE OF EXISTING SHIPBUIL-  
DING STANDARDS, COMMERCIAL &  
NAVY,

( E X A M P L E )    S T A N D A R D   I T E M S   C A T E G O R I Z E D   B Y   P R I O R I T Y   O R D E R S

APPENDIX C

EXPLANATIONS

1.    RATIONALE

This column indicates the effects or benefits of standardization.

2 to 4 most effective rationales are selected for each standard.

- 01 -    Improve communication, save labour  
         (e.g. smoother negotiations, minimize conflicts)
- 02 -    Improve approval work, save labour  
         (e.g. simplify plan approval, shorten approval time)
- 03 :    Improve inspection work, save labour  
         (e.g. simplify/eliminate inspection, shorten inspection  
         time, eliminate duplication)
- 04 -    Improve design/engineering work, save labour  
         (e.g. reduce engineering manhours, minimize design  
         changes, improve accuracy of drawings)
- 05 -    Improve purchasing work, save labour  
         (e.g. simplify ordering, minimize estimation work)
- 06 -    Improve production, save labour  
         (e.g. improve productivity, reduce manhours)
- 07 -    Stabilize or improve technology level  
         (e.g. stabilize and improve engineering and production  
         technology, eliminate inconsistency in design or speci-  
         fications)
- 08 -    Maintain or improve quality  
         (e.g. maintain quality, improve reliability)
- 09 -    Reduce cost  
         (e.g. avoid over design, reduce tailor-made products) -
- 10 -    Shorten delivery time  
         (e.g. reduce purchasing time, allow stocks)



2. STATUS

This column indicates the organization, rule or regulation, institute, etc., issuing and controlling the standard.

3. CATEGORY

This column indicates characteristics of the standard.

N - National standard

I - Industry-wide standard

H - Company in-house standard

4. F-25 COMMITTEE

This column indicates the code number of ASTM F-25 sub-committees.

NO	ITEM	RATIO -NALE	STATUS	CATE -GORY	F-25 COMM
1	Manhole cover, Access hatch cover, etc.	02 04 05 08	MASS ABS ISO	I	03
2	Rigging, Lines, Blocks	02 04 05 08	MASS	I	03
3	Anchor	02 04 05 08	MASS ABS ISO	N	03
4	Anchor chain	02 04 05 08	MASS ABS ISO	N	03
5	Anchor chain controller	02 04 05 08	MASS ISO	N	03
6	Bitt, Bollard	02 04 05 08	PCC ISO	N	03
7	Chocks	02 04 05 08	PCC ISO	I	03
8	Eye plate, Ring plate	04 05 08 10	MASS DIN JIS	I	03
9	Handrail, Handrail stanchion	04 05 08 10	MASS ISO	I	03
10	Step, Vertical ladder	04 05 08 10	MASS ISO	I	03
11	Pilot ladder	02 04 05 08	ISO	N	03
12	Weather tight steel door	02 04 05 08	MASS ISO	I	03
13	Round scuttle, Window	02 04 05 08	MASS ABS ISO	I	03
14	Bottom plug	04 05 08 10	ISO	I	03
15					
16					
17					

Table - 1 Short-term Products Standards

N0	ITEM	RATIO -NALE	STATUS	CATE -GORY	F-25 COMM
1	Bosun store equipment (bosun chair etc.)	01 04 05 08	MASS JIS	I	03
2	Derrick boom	02 04 05 08	MASS ISO	I	03
3	Goose neck bracket	02 04 05 08	MASS ISO	I	03
4	Topping bracket	02 04 05 08	MASS ISO	I	03
5	Boom rest	04 05 08 09	MASS JIS	I	03
6	Fittings of bitter end of anchor chain	04 05 08 09	JIS	I	03
7	Fairleader	04 05 08 09	DIN JIS	I/H	03
8	Ladder and platform	04 05 08 09	MASS	I	03
9	Ladder and platform (tank, hold)	04 05 08 09	MASS	I	03
10	Ladder and platform (engine room)	04 05 08 09	MASS	I	03
11	Ladder (in accommodation)	04 05 08 09	MASS	I	03
12	Ship's side ladder for pilot	02 04 05 08	PCC	I	03
13	Door for accommodation	04 05 08 09	MASS	I	03
14	Door for store (non-tight door)	04 05 08 09	JIS	I/H	03
15	Inventories	04 05 08 10	MASS FED MIL	I/H	03
16	Fittings for store and work space (shelf etc.)	04 05 08 09	MASS FED	I/H	03
17	Hydrant box, Hose box	04 05 08 09	MASS ABS	I/H	03

Table - 2 Mid-term Products Standards

NO	ITEM	RATIO -NALE	STATUS	CATE -GORY	F-25 COMM
1	Side port	02 04 05 08	MASS	I/H	03
2	Water tight door	02 04 05 08	ABS JIS	I	03
3	Securing device for cargo hatch cover	04 05 08 09	MASS ABS	I/H	03
4	Mast, Derrick post	04 05 08 07	MASS ABS	H	03
5	Ventrisher (cargo/inert gas vent)	04 05 08 09	ABS	I	03
6	Pressure vacuum breaker	04 05 08 09	ABS	I	03
7	Rudder carrier	04 05 08 09	MASS ABS	I/H	03
8	Tanks (miscellaneous use)	04 05 08 09	-	I/H	03
9	Container lashing device	04 05 08 09	ABS	I/H	03
10					
11					
12					
13					
14					
15					
16					
17					

Table - 3 Long-term Products Standards

## RECOMMENDED ORGANIZATIONAL STRUCTURE FOR STANDARDS DEVELOPMENT

### A) National Standards

<u>Work Process</u>	<u>Responsible Organization</u>
- Planning, long-range plans goals	MarAd (commercial, actual planning assigned to SNAME SP-6)
- Development	ANSI (related to ISO)  ASTM, F-25 (others)
- Approval/Authorization	SNAME SP-6.
- Enactment	MarAd
- Publication/Distribution	ANSI or ASTM
- Follow-up	SNAME SP-6 (actual work assigned to ANSI or ASTM)
- Recognition, re compliance w/international, Federal laws, regulations	U. S. C. G.

## 8 Industry Voluntary Standards

Work Process	Responsible Organizations
- Planning, long-range plan goals	SNAME SP- 6
- Development	ASTM F- 25
- Approval /Authorization	SNAME SP- 6
- Enactment	ASTM
- Publication	ASTM

**03 502 5 2**

F-25	TYPE OF	POTENTIAL	ORIG	NO. OF	RV	RF	SYNONYMS	SYNONYMS	SYNONYMS	MOD	SYSTEM	TSK				
COMM	SWBS	STANDARD	BENEFITS	CODE	STANDARD	YK	YK	ORIGU	STANDARD-1 YR	ORIGU	STANDARD-2 YR	ORIGU	STANDARD-3 YR	REQD	UNITS	NO
S U B J E C T C A T E G O R Y													S T A N D A R D T I T L E			
C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9	C-10	C-11	C-12	C-13				
03	582	5	2	DIN	81921	69								3	M	3
	BITT. BOLLARD AND CLEAT										BELAYING CLEATS FOR FIBRE ROPES					
03	582	5	2	HMN	62034	72								3	M	3
	BITT. BOLLARD AND CLEAT										BOLLARDS. SUMMARY					
03	582	5	2	JIS	F2001	75								3	M	3
	BITT. BOLLARD AND CLEAT										BOLLARDS					
03	582	5	2	DIN	81915	69								3	M	3
	CHOCK										MULTI-PURPOSE CHOCKS					
03	582	5	2	HMN	46002-1	72								3	M	3
	CHOCK										ROLLER CHOCK. SUMMARY					
03	582	5	2	JIS	F2003	68								3	M	3
	CHOCK										CAST IRON DECK END ROLLERS					
03	582	5	2	JIS	F2004	76								3	M	3
	CHOCK										STEEL PLATE DECK END ROLLERS					
03	582	5	2	JIS	F2005	75								3	M	3
	CHOCK										CLOSED CHOCKS					
03	582	5	2	JIS	F2017	75								3	M	3
	CHOCK										PANAMA CHOCKS					
03	582	5	2	DIN	81906	72								3	M	3
	FAIRLEAD										PEDESTAL FAIRLEADS (OLD MAN FAIRLEADS)					
03	582	5	2	HMN	46002-2	74								3	M	3
	FAIRLEAD										GUIDE ROLLER. SUMMARY					
03	582	5	2	JIS	F2014	69	75							3	M	3
	FAIRLEAD										FAIR-LEADS					

596

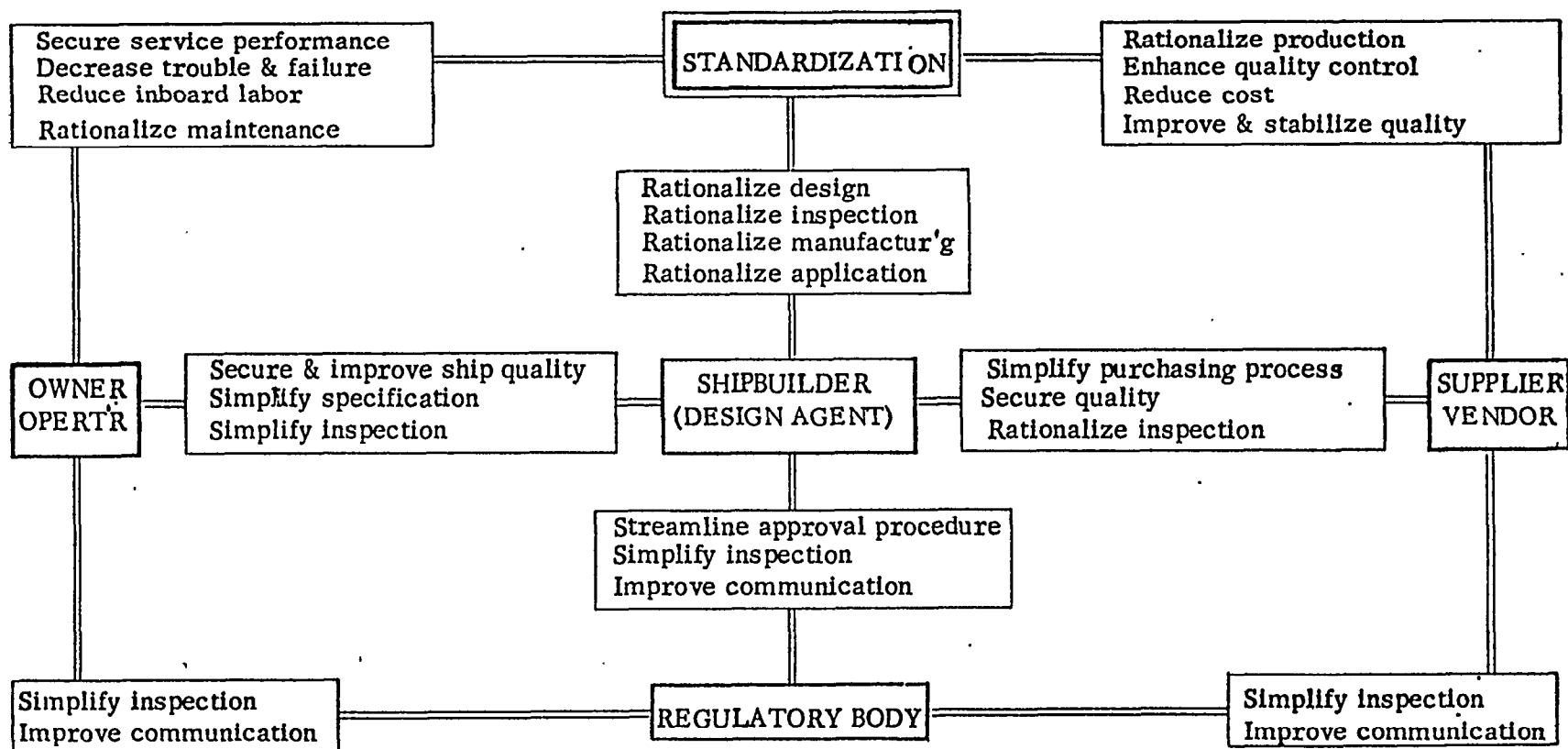


Figure 1-1 Effects of Standardization



## APPENDIX A: IREAPS TECHNICAL SYMPOSIUM AGENDA

### TUESDAY, SEPTEMBER 15

**8:00**     **REGISTRATION**                      **GRAND FOYER**  
**- 3:30**

**9:15**     **GENERAL SESSION**     **FRANCIS SCOTT KEY**  
    **BALLROOM, NORTH & CENTER**  
**SESSION CHAIRMAN:**     **J.R. Vander Schaaf**  
    **Bath Iron Works**

- **WELCOME**  
    J.C. Estes, Bethlehem Steel Corp.
- **SHIP PRODUCTION COMMITTEE OVERVIEW**  
    E.L. Peterson, Peterson Builders, Inc.
- SHIP PRODUCTION COMMITTEE PANEL**  
**OVERVIEWS:**
  - **SP-2 — Outfitting and Production Aids**  
    L.D. Chirillo, Todd Pacific Shipyards Corp.

**10:30**     **INFORMAL DISCUSSION PERIOD**

**11:00**     **GENERAL SESSION**     **FRANCIS SCOTT KEY**  
    **BALLROOM, NORTH & CENTER**  
**SESSION CHAIRMAN:**     **E.L. Peterson**  
    **Peterson Builders**

**SPC PANEL OVERVIEWS (contd)**

- **SP-1 & 3 — Facilities and Environmental Effects**  
    R. Price, Avondale Shipyards, Inc.
- **A PROGRESS REPORT ON THE IREAPS PROGRAM**  
    E.R. Bangs, IIT Research Institute

**12:00**     **LUNCH**

**1:30**     **GENERAL SESSION**     **FRANCIS SCOTT KEY**  
    **BALLROOM, NORTH & CENTER**  
**SESSION CHAIRMAN:**     **L.D. Chirillo**  
    **Todd Pacific Shipyards**

**SPC PANEL OVERVIEWS (contd)**

- **SP-4 — Design/Production Integration**  
    T.J. O'Donohue, Newport News Shipbuilding
- **Introduction-Ship Producibility Research Program**  
    J.C. Mason, Bath Iron Works Corp.
- **SP-6 — The National Shipbuilding Standards Program**  
    S. Wolkow, Bath Iron Works Corp.
- **SP-8 — The Shipbuilding Industrial Engineering Program**  
    J.R. Fortin, Bath Iron Works Corp.

**3:00**     **INFORMAL DISCUSSION PERIOD**

**3:30**     **GENERAL SESSION**     **FRANCIS SCOTT KEY**  
    **BALLROOM, NORTH & CENTER**  
**SESSION CHAIRMAN:**     **E.R. Bangs**  
    **IIT Research Institute**

**SPC PANEL OVERVIEWS (contd)**

- **SP-7 — Shipyard Welding**  
    B.C. Howser, Newport News Shipbuilding

- **0-23-1 — Surface Preparation and Coatings**  
    J. Peart, Avondale Shipyards, Inc.
- **SP-9 — Education**  
    H. Bunch, University of Michigan

**5:15**     **RECEPTION**                                      **GRAND FOYER**  
**- 6:15**                                      **Sponsored by: IIT Research Institute**

### WEDNESDAY, SEPTEMBER 16

**8:00**     **REGISTRATION**                                      **GRAND FOYER**  
**- 3:30**

**8:30**     **Concurrent Sessions**

**SESSION 1**                                      **FRANCIS SCOTT KEY**  
    **BALLROOM, NORTH & CENTER**  
**SESSION CHAIRMAN:**     **P.M. Cofoni**  
    **General Dynamics**

- **THE AUTOFIT CAD/CAM SYSTEM FOR PIPING ENGINEERING: OPERATIONAL EXPERIENCE AND DEVELOPMENT STATUS**  
    F. Dahle, Shipping Research Services A/S
- **AUTODRAW: AUTOKON'S INTERACTIVE GRAPHICS SYSTEM FOR VIEWING AND MANIPULATING STRUCTURAL MODEL DATA INTO COMPLETE DRAWING DOCUMENTATION**  
    F. van Cuilenborg, Shipping Research Services A/S
- **USING AUTOKON FROM EARLY DESIGN: RECENT EXPERIENCE FROM ACTUAL SHIP DESIGNS**  
    H. Oigaarden, Shipping Research Services A/S

**SESSION 2**                                      **FRANCIS SCOTT KEY**  
    **BALLROOM, SOUTH**  
**SESSION CHAIRMAN:**     **R. Price**  
    **Avondale Shipyards**

- **JAPANESE SURFACE PREPARATION AND COATING METHODOLOGY AND MATERIALS**  
    G. Soltz, Consultant
- **IMPLEMENTATION OF PRODUCTION ENGINEERING TECHNIQUES**  
    M. Bell, A & P Appledore, Ltd.  
    L. Flora, Norshipco
- **A MANAGEMENT SIMULATOR FOR SHOP STORES IN THE U.S. NAVAL SHIPYARDS**  
    H.E. Warren, California State University — Los Angeles

**10:00**     **INFORMAL DISCUSSION PERIOD**

**10:30**     **Concurrent Sessions**

**SESSION 1**                                      **FRANCIS SCOTT KEY**  
    **BALLROOM, NORTH & CENTER**

SESSION CHAIRMAN: J. Wasserboehr  
National Steel  
Shipbuilding

- U.S. NAVY CAD/CAM PROGRAM HULL  
STRUCTURE (HULSTRX) DEVELOPMENT  
OVERVIEW  
D. Helgeson, Advanced Marine Enterprises, Inc.  
E. Byler, Advanced Marine Enterprises, Inc.
- 1 BRITSHIPS - SHIPBUILDING CAD/CAM  
IN PRODUCTIVE APPLICATION  
I.M. Tolmie, British Ship Research Association
- A NATIONAL COALITION FOR THE  
SHIPBUILDING TECHNOLOGY PROGRAM  
F.W. Helming, SofTech, Inc.

## SESSION 2 FRANCIS SCOTT KEY BALLROOM, SOUTH

SESSION CHAIRMAN: J. Peart  
Avondale Shipyards

- ECONOMIC BENEFITS AND TECHNOLOGY  
OF CU/NI SHIP HULL SHEATHING  
L.W. Sandor, The Franklin Research Center  
L.M. Schetky, International Copper Research  
Association, Inc.  
E.W. Thiele, Copper Development Association
- A CNC SHEETMETAL FABRICATION  
SYSTEM FOR PRODUCTION OF SHIPS  
VENTILATION COMPONENTS AND  
FLATWORK  
T.R. Galie, Naval Ship Systems  
Engineering Station  
D. Blais, Bath Iron Works Corp.
- 1 SHIP STRUCTURAL COST PROGRAM  
A. Furio, David W. Taylor Naval Ship  
Research and Development Center

12:00 LUNCH

## 1:30 GENERAL SESSION FRANCIS SCOTT KEY BALLROOM, NORTH & CENTER

SESSION CHAIRMAN: R.C. Moore  
Newport News  
Shipbuilding

- IMPLEMENTATION OF INTERACTIVE  
GRAPHICS FOR STRUCTURAL DESIGN  
AND PART DEFINITION  
G. Panciera, General Dynamics  
D. Palmer, General Dynamics
- HUMAN PERFORMANCE ENGINEERING  
AS A GUARANTEED METHOD OF  
PRODUCTIVITY INCREASE  
D.C. Anderson, University of Notre Dame

3:00 INFORMAL DISCUSSION PERIOD

## 3:30 GENERAL SESSION FRANCIS SCOTT KEY BALLROOM, NORTH & CENTER

SESSION CHAIRMAN: T.J. O'Donohue  
Newport News  
Shipbuilding

1 PRODUCTIVITY, NAVY STYLE  
J.W. Tweeddale, U.S. Navy

1 QUALITY CIRCLES, DOING BUSINESS  
BETTER AT THE PHILADELPHIA  
NAVAL SHIPYARD  
R. Bradley, Philadelphia Naval Shipyard

## THURSDAY, SEPTEMBER 17

8:00 REGISTRATION GRAND FOYER  
10:30

8:30 Concurrent Sessions

## SESSION 1 FRANCIS SCOTT KEY BALLROOM, NORTH & CENTER

SESSION CHAIRMAN: B.G. Bohi  
Bethlehem Steel Corp.

- THE NEW INTERACTIVE GRAPHICS  
SYSTEM AT CALI AND ASSOCIATES  
L. Lowery, Cali and Associates, Inc.

1 THE MOST COMPUTER SYSTEMS -  
SHIPYARD APPLICATION  
L. Kuh, H.B. Maynard & Co., Inc.

1 INTERACTIVE PARTS DEFINITION PROJECT  
R.C. Moore, Newport News Shipbuilding  
A.F. Kaun, Newport News Shipbuilding

## SESSION 2 FRANCIS SCOTT KEY BALLROOM, SOUTH

SESSION CHAIRMAN: H.M. Bunch  
University of Michigan

- AN APPROACH TO SUCCESSFUL SHIPYARD  
PLANNING AND SCHEDULING  
S. Knapp, SPAR Associates, Inc.

- PLANNING AND SCHEDULING SHIP  
CONSTRUCTION SUBJECT TO LIMITED  
RESOURCES  
L.C. Deschamps, SPAR Associates, Inc.

1 IMPLEMENTATION OF A PRACTICAL  
PLANNING AND PRODUCTION CONTROL  
SYSTEM IN SMALL AND MEDIUM  
SIZED SHIPYARDS  
J.N. Spillane, Shipbuilding Consultants, Inc.

10:00 INFORMAL DISCUSSION PERIOD

## 10:30 GENERAL SESSION FRANCIS SCOTT KEY BALLROOM, NORTH & CENTER

SESSION CHAIRMAN: R. Lovdahl  
Todd Pacific Shipyards

- 1 INTERACTIVE STEEL STRUCTURE  
DEFINITION AND GENERATION: EFFECTS  
ON MANPOWER AND LEADING TIME  
R. Di Luca, Italcantieri S.P.A.
- 1 A PRACTICAL APPROACH TO USING  
STANDARD SOFTWARE PACKAGES  
IN SMALL SHIPYARDS  
G. Hoffman, St. Louis Ship
- AN INTRODUCTION TO ENGINEERING  
MODELS (WITH A CASE STUDY IN THE  
SHIPBUILDING INDUSTRY) -  
A CHALLENGE  
J.W. Rohrer, U.S.A. Models  
G.L. Kraine, Sun Shipbuilding and  
Dry Dock Company
- 12:00 LUNCH
- 1:30 GENERAL SESSION FRANCIS SCOTT KEY  
BALLROOM NORTH & CENTER  
SESSION CHAIRMAN: D.J. Martin  
National Steel &  
Shipbuilding
- 1 PRODUCTIBILITY FROM CONCEPTUAL  
DESIGN TO SHIP CONSTRUCTION  
I.S. MacDougall A & P Appledore. Ltd.
- COMPUTER ASSISTED PROCESS  
MANUFACTURING AND ASSEMBLY -  
A FIRST STEP TOWARDS INTEGRATION  
A. Houtzeel, Organization for Industrial  
Research, Inc.
- 3:00 INFORMAL DISCUSSION PERIOD
- 3:30 GENERAL SESSION FRANCIS SCOTT KEY  
BALLROOM NORTH & CENTER  
SESSION CHAIRMAN: L.M. Thorell  
Todd Pacific Shipyards
- PRODUCTIVITY - MANAGEMENT'S  
BONUS (!!) OR FAILURE (??)  
F.H. Rack, Shipbuilding Consultants, Inc.
- 1 THE U.S. SHIPBUILDING STANDARDS  
PROGRAM - LONG RANGE PLAN  
Y. Ichinose. IHI Maxine Technology, Inc.
- 4:30 ADJOURNMENT



APPENDIX B: IREAPS TECHNICAL SYMPOSIUM ATTENDANCE LIST

Baltimore, Maryland

SEPTEMBER 15-17, 1981

A&P APPLIEDORE LIMITED

Northumbrian Way, Killingworth  
Newcastle Upon Tyne, ENGLAND

Malcolm Bell  
Ship Production Engineer  
I. S. MacDougall  
Director

ADVANCED MARINE ENTERPRISES

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System Analyst  
Eric Byler  
Systems Analyst  
Dave Helgeson  
Chief Hull Scientific Sect.  
Ricky W. Lee  
Sr. Designer  
Otto P. Jons  
V.P. Engineering

ADVANCED TECHNOLOGY, INC.

1725 Jefferson Davis Hwy - Suite 300  
Arlington, VA 22202

Stephen T. Fisher  
Senior Program Engineer

THE AMERICAN SHIP BUILDING COMPANY

AMSHIP Div.  
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VP Planning & Production Control  
Ray Francis  
Manager-Engineering  
Ed Wingenroth  
Welding Engineer

ANDERSON ENGINEERS INC.  
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Carnegie, PA 15106

Gary L. Schnorrenberg  
National Sales Manager

D. APPLETON CO., INC. (DACOM)  
P.O. Box 838  
Manhattan Beach, CA 90266

A. Wayne Snodgrass  
Project Manager

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Denver, CO 80233

Walt Simpson  
Manager of Applications Dev.

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New Orleans, LA 70150

John Peart  
Richard Price

AVONDALE SHIPYARDS INC.  
76 Dunlith Ct.  
Marrero, LA 70072

Vincent H. Nuzzo  
Supt. Mold Loft

BALTIMORE MARINE SERVICES  
22 W. Padonia - Suite C252  
Timonium, MD 21093

Robert Dennison  
Gordon Kinkaid  
President  
Tom Kneeshaw  
VP

BAND, LAVIS & ASSOCIATES INC.  
670 Ritchie Highway  
Severna Pk, MD 21146

Paul R. Van Mater, Jr  
Senior Naval Architect

BATH IRON WORKS  
700 Washington Street  
Bath, Maine 04530

David Blais

J. R. Erikson  
FFG Design Mgr.

J. R. Fortin

J. C. Mason

Richard B. Siek  
NC Project Coordinator

D. H. Thompson  
Producibility Project Engineer

James R. Vander Schaaf  
Supvr. of Planning Systems Development

S. Wolkow

BAY SHIPBUILDING CORP.  
605 N. Third Ave.  
Sturgeon Bay, WI 54235

Robert H. Miller  
VP, Director of Engineering

BETHLEHEM STEEL CORP.  
CTD-Sparrows Point Shipyard  
Sparrows Point, MD 21219

V. G. Adams  
Hull Drafting Dept.

Bruce Bohl  
Lead/Programmer/Analyst

Karl E. Briers  
System Engineer

Martin Castle  
Sr. Designer

Kevin D. Dyer  
Sr. Engr.

Edwin Faus  
Industrial Engineer

Isaac Gemmell  
Chief Electrical Draftsman

Sudarshan K. Gupta  
Senior Engineer

Joseph Haslbeck  
Chief Machinery Draftsman

Nicholas V. Haynes  
supt., Production Engineering

BETHLEHEM STEEL CORP. (continued)  
CTD-Sparrows Point Shipyard  
Sparrows Point, MD 21219

Art Huge  
Shipyard Controller-Accounting Dept.

Henry Jones  
Plant Engineer

James P. Kozo  
Project Manager

Ed Marcavage  
Computer Applications Sect..

William P. McCloskey  
General Foreman-Electrical & Sheet Metal

Peter McNair  
Planning

Alex Miller  
Chief Planner

Mike Miller  
Planning

T. L. Mullin  
Chief Draftsman

Tahanh Minh Ngo  
Computer Applications Sect.

Dan Romanchuk  
General Supt.

Gerald Simmons  
Pipe Foreman

Frank J. Slyker  
Chief, Basic Ship Design

Norm Smith  
Supt. Outfitting

John Spies  
Computer Applications Sect.

David T. Vermette  
Exempt. Supervisor

Dave Watson

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Martin Tower  
Bethlehem, PA 18016

Henry A. Baierlein  
Supt. Maint. Practices

John C. Estes  
Assistant VP, Shipbuilding

Eugene Schorsch  
Manager

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Joseph W. Wade  
Mgr. Eastern Regional Sales



CDI MARINE COMPANY  
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William H. Hunley  
Robert Van Buiten

COLLINGWOOD SHIPYARDS  
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Collingwood, ONT., Canada

Laurie Moore  
Systems Analyst

CORPORATE-TECH PLANNING INC.  
John Hart Mansion-The Hill  
Portsmouth, NH 03801

Rodney A. Robinson  
Executive Staff Member

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P.O. 130 Lauzon Levis  
Quebec, Canada

M. Donni son  
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Marc-Guy Letourneau  
Designer and Scientific Analysis  
Charles Methot  
Steel Work Planning Manager

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The SPC chairman is:	Mr. Ellsworth L. Peterson President Peterson Builders, Inc. 101 Pennsylvania Street Sturgeon Bay, Wisconsin 54235	414/743-5577
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Panel SP-2: Outfitting and Production Aids	Mr. Louis D. Chirillo R&D Program Manager Todd Pacific Shipyards Corporation Seattle Division 1801 16th Avenue, S.W. Seattle, Washington 98124	206/623-1635 x497
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Panel SP-6: Standards	Mr. John C. Mason	207/443-3311
Panel SP-8: Industrial Engineering	MarAd Program Manager Bath Iron Works Corporation 700 Washington Street Bath, Maine 04530	X2146

Panel SP-7: Welding	Mr. B. C. Howser Newport News Shipbuilding 4101 Washington Avenue Newport News, VA 23607	804/380-2394
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